1946–47.

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

TWENTY-FIRST ANNUAL REPORT

OF THE

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

FOR THE

YEAR ENDED 30TH JUNE, 1947.

Presented pursuant to Statute; ordered to be printed, 21*st November,* 1947.

[*Cost of Paper.*—Preparation, not given; 622 copies; approximate cost of printing and publishing, £158.]

Printed and published for the GOVERNMENT of the COMMONWEALTH OF AUSTRALIA by L. F. JOHNSTON, Commonwealth Government Printer Canberra.

(Printed in Australia.)

No. 43 [GROUP F.]—F.7446.—PRICE 6s.

CONTENTS.

CONTENTS—*continued.*

COMMONWEALTH OF AUSTRALIA.

Council for Scientific and Industrial Research.

TWENTY-FIRST ANNUAL REPORT (FOR YEAR ENDED 30TH JUNE, 1947).

I. INTRODUCTORY.

1. *General.*—The Council for Scientific and Industrial Research was established in 1926 by the re-organization of the existing Institute of Science and Industry. The powers and functions of the Council are defined by the *Science and Industry Research Act* 1920-1945, and include the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries; the training of research workers; the making of grants in aid of pure research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; and the establishment of an information service relating to scientific and technical matters.

2. *Council and Executive Committee.*—There have been further changes in the membership of the Council during the past year. Mr. D. A. Mountjoy was appointed as a member of the Executive Committee for a period of three years as from 20th November, 1946. Mr. A. J. Gibson was appointed as Chairman of the New South Wales State Committee, thus becoming a member of the full Council, for a period expiring on 31st December, 1948; he fills the vacancy arising out of the transfer of the former Chairman (Dr. I. Clunies Ross) to a position on the Executive Committee in Melbourne. Finally, Professor Ashby, of the University of Sydney, resigned from the Council on his departure from Australia to occupy a Chair in the University of Manchester.

3. *Wool and Textile Research.*—In the previous report, it was mentioned that it was proposed to establish a Division of Textile Research, and that the position of Chief of that Division was being advertised in Australia and overseas. No appointment has yet been made, and consideration is now being given to the establishment of two Divisions. One would develop more fundamental work on the chemistry and physics of the wool fibre, and the other would concentrate on the technology of the spinning and utilization of wool. In the meantime, one or two officers of the Council who had previously been associated with other Divisions have been diverted to wool textile work in existing laboratories. It is hoped at an early stage to commence some work on the degreasing of wool by means of hydrocarbon solvents as distinct from the normal soap and water scours. It is also hoped that University research workers will be encouraged to study the fundamental structure and properties of the wool fibre and in that way facilitate the ultimate establishment of the fundamental Division mentioned above.

4. *Division of Soils—Appointment of Chief.*—At the close of the period under review Professor Prescott, who had been Chief of the Council's Division of Soils since its formation in 1929, resigned. He will continue, however, in his position as Director of the Waite Agricultural Research Institute of the University of Adelaide, and will continue to co-operate with the Council in various ways. His place as Chief of the Division has now been filled by the appointment of Mr. J. K. Taylor, formerly Deputy Chief of the Division.

5. *New Investigations.*—During the year, a commencement has been made with several investigations in fields of work not covered by the existing Divisions and Sections.

(i) *Meteorological Physics.*—One such activity is in the field of meteorological physics. Although for many years systematic meteorologists have studied the day-to-day changes in Australian weather, studies of the fundamental phenomena underlying these changes have rarely been undertaken. Nevertheless, it has been felt that the importance of weather to Australia undoubtedly justifies a much more intensive study of the physics of the atmosphere, as only a knowledge of the basic physical phenomena can ultimately lead to the possibility of making successful long-range weather forecasts. Following discussions with officers of the Commonwealth Meteorological Bureau, the Council has now appointed an officer to take charge of the Meteorological Physics Section. He will be advised by the Meteorological Research Consultative Committee on which the Meteorological Bureau, the School of Meteorology in the University of Melbourne, and the Commonwealth Observatory, Mt. Stromlo, are represented. A programme of research has been drawn up and staff is at present being recruited. It is proposed that in the first few years the work should centre on an examination of the detailed conditions of the atmosphere over a small area. This offers a field for fundamental research and, by the light it should throw on the mechanism of meteorological changes, should have a wide variety of applications over the whole range of weather problems.

(ii) *Metallurgy.*—For some time past, the Council has had under consideration the initiation of investigations in the field of secondary metallurgy. It already has within the Division of Aeronautics a small group of metallurgical investigators, but this group has of necessity confined its attention in the main to rather specific problems arising in connexion with the work of the Division, and has not been able to undertake much work of a fundamental nature. Nevertheless, the development of the engineering industries of Australia depends to a considerable extent upon an adequate knowledge of the physical and chemical properties of metals. The Council has been fortunate in arranging for the establishment of a small co-operative section of metallurgy to be accommodated in the Research School of Metallurgy at the University of Melbourne. The section is directed by the Research Professor of Metallurgy in the University (Professor J. N. Greenwood). Two or three investigators have now been appointed, and are working with Professor Greenwood. Initially, the programme of work will include studies on the properties of metals at high temperatures, preparation of metal compacts from metal powders, and the application of X-rays to the studies of metals and alloys.

(iii) *Nuclear Physics.*—A commencement has been made in gathering together a small team of chemists and engineers to study the utilization of atomic energy for industrial purposes. The officers appointed are

being sent to the United Kingdom, where they will work at the Atomic Energy Research Establishment at Harwell. Arrangements have also been made with the University of Melbourne for a co-operative programme of research in nuclear physics at the Physics School. As a result of these activities, it is hoped that Australia will have available a small team of trained scientific men who should serve as a nucleus of staff for any atomic energy projects which may be undertaken in Australia.

(iv) *Radio-active Tracer Elements.*—An important offshoot of the atomic bomb project in the United States of America and Canada is the quantity production of a number of artificially radio-active elements. This makes possible a great extension of the use of tracer element techniques in physical, biological, and medical research, and provides a potent tool for investigation in these fields. In collaboration with the Commonwealth Department of Health, arrangements have been made to procure supplies of radio-active isotopes from overseas and to develop a service for their handling and dissemination to research workers in Australia. An officer has been appointed for this work and he will be available to act as a consultant to research workers desirous of starting experimental work with any specific element. A Tracer Element Research Committee has been established to advise the Council on this project.

6. *Coal Dust—Visit of the Late Professor T. David Jones.*—During the year, the Federal Cabinet decided that the Council should be empowered to proceed at once with the setting up of research facilities to carry out investigations into the prevention of dust in coal mines, and to that end, if need be, to obtain expert assistance from overseas to assist in the inquiry. Arrangements were subsequently made for the late Professor T. David Jones, formerly of the University of Wales and lately Professor of Mining at the University of Birmingham, to visit the various Australian coal-fields and to report on his findings. He left Australia at the end of May, 1947, after having submitted a report which indicated that much of the trouble existing in Australian coal mines could be considerably alleviated by the application of already established methods of dust prevention. He recommended, however, that the Council should undertake investigations into the best means of measuring dust concentrations in mines, and that a more detailed survey of the conditions in the mines should be made. He suggested, further, that the work undertaken should be carried out in close co-operation with the Joint Coal Board, which would be the body responsible for carrying into practical effect recommendations for the alleviation of dusty conditions in mines. Concurrently with the visit of Professor Jones, the Council established a Coal Dust Research Advisory Committee to advise on a programme of research. That Committee has now considered the report of Professor Jones and has also collected information on its own behalf.

The whole matter is still under consideration by the Council and the other bodies concerned.

7. *Australian National Antarctic Research Expedition.*—During the year, attention has been given, at the request of the Department of External Affairs, to the more scientific aspects of plans for the Australian Expedition which is to be sent to the Antarctic during the summer of 1947-48. In particular, the council has played a considerable part in consultation with other interested bodies such as the Commonwealth Bureau of Mineral Resources, the Commonwealth Meteorological Bureau, and the Universities of Melbourne and Sydney in drawing up plans for the scientific work of the Expedition. It is anticipated that the Expedition will pay particular attention to problems of geophysics, including meteorology, the earth's magnetism, cosmic rays, and, possibly, radio propagation.

8. *National Association of Testing Authorities.*—Some time ago, the Council set up a Committee on Standards and Testing to explore requirements from the point of view of providing Australian secondary industry with improved testing facilities. Arising out of recommendations of the Committee, a conference was convened by the Government under the aegis of the Council late in 1945. It was then agreed that steps should be taken to co-ordinate the activities of the various laboratories which already provided industry with a service for the measurement and testing of materials, and that this objective might be attained through the formation, on a purely voluntary basis, of a National Association of Testing Authorities. Existing laboratories would retain their present autonomy and would continue to perform their existing functions, but in addition would be licensed to endorse their certificates of test in the name of the Association, these endorsed certificates to have Commonwealth-wide recognition indicating that such tests had been carried out in accordance with procedures agreed to by members of the Association. The recommendations have now been endorsed by Federal and State Governments and considerable progress made with the establishment of the Association. The Council is acting as the means of liaison between the Association and the Government. In the initial stages until the Association has built up a staff of its own, the Council is providing it with secretarial and clerical assistance.

9. *Overseas Training.*—In the previous report, mention was made of the scheme for which ministerial approval had been obtained for the sending abroad of up to 25 officers in any year in order that they might collect information on new developments in scientific research and to acquire general experience in research and a training in new techniques. That scheme is now in full operation, and at the present time 25 officers are abroad. A number of studentships have also been created with a somewhat similar purpose in view, but more particularly for the training of recent graduates. At the present time, 28 students are located in United Kingdom laboratories and a few in United States laboratories while they are becoming acquainted with the latest developments and acquiring a breadth of vision and inspiration which will be of great value in their future work in Australia.

10. *Collaboration with the Universities.*—The Council has for long adopted the policy of co-operating with other organizations to the greatest possible extent. As a result, the volume of work in which various scientific bodies, and in particular State Departments of Agriculture and universities, are interested has now grown to large dimensions and is mentioned in the main body of the report that follows.

With the development of the Council's investigations in the physical sciences, the help afforded by the Universities has become increasingly important. For example, at Sydney, the National Standards Laboratory, the Radiophysics Laboratory, and the McMaster Laboratory are all accommodated in the grounds of the University. Similarly, in Melbourne, the Section of Tribophysics is housed in the University's Department of Chemistry, while in Adelaide, the Division of Biochemistry and General Nutrition is located in the University grounds. The close proximity of these laboratories to University facilities and the opportunities for consultation and exchange of views with members of the University staffs is of the greatest benefit.

Further, in developing new lines of work, particularly on the more fundamental side, the Council frequently turns to the Universities for assistance. For example, in Melbourne, a number of men are being trained in nuclear physics at the Physics School, and at the Research School of Metallurgy a programme of co-operative work has recently been commenced. There

is good reason to believe that such association with Universities, which are the natural home of fundamental research, is a source of mutual strength that is of no little national importance.

11. *Finance.*—Section XXII. of this Report gives details of expenditure by the Council during the financial year 1946-47 of a sum totalling £1,352,522. Of this amount £119,321 was contributed other than directly from the Commonwealth Treasury and this amount included £46,448 expended from the Wool Industry Fund. In addition, the sum of £84,469 was expended on wool and textile research from funds derived as a result of the passing of the *Wool Use Promotion Act* 1945. Certain other expenditure involved in erection costs of buildings was also incurred on behalf of the Council. The Council is particularly gratified with the way in which contributory bodies continue to support it, and with the marked interest evinced by, and donations for co-operative research received from, certain sections of industry. Among the many contributions received, reference may be made to those of the Commonwealth Bank, the Wool Scourers', Carbonizers', and Fellmongers' Federation of Australia, the Australian Cattle Research Association, the George Aitken Pastoral Research Trust, the Dried Fruits Control Board, the New South Wales Water Conservation and Irrigation Commission, the Cement Manufacturers' Association, the Rural Bank of New South Wales, and other co-operative bodies associated wth soils and irrigation work, the timber industry, and the pulp and paper industry.

II. PLANT INVESTIGATIONS.

1. *General.*—During the year the pasture improvement programme of the Division of Plant Industry, which was held up by the war, was reopened, but with augmented effort on wool pastures because of the profound importance of wool to the welfare of Australia. Despite a shortage of personnel, a satisfactory start has been made.

The development of the Regional Station at Deniliquin is going on steadily, irrigation channels having been constructed and some experiment areas planted.

The first reconnaissance survey in North Australia was completed during the year, and a report with maps prepared for submission to the Northern Australia Development Committee. The survey party encountered many difficulties of terrain, but nevertheless was very successful in its work. Future work in North Australia will be helped by the establishment of a station at Katherine where intensive work on both dry and irrigated crops will be done. The Division is co-operating with the Department of Agriculture of Western Australia at the Kimberley Research Station on the Ord River, near Wyndham.

As with pasture work, so with tobacco the exigencies of war tended to a reduction of effort on behalf of that industry. In order to re-establish the work on a sound basis the officer in charge was sent to North America to investigate the latest developments there. Since his return, a conference between the Council and State Technical Officers was held in Brisbane to determine the co-operative programme for the succeeding five years. It was, fortunately, possible for the Tobacco Research Officer of the D.S.I.R. of New Zealand to attend the conference, and to give the benefit of experience in that Dominion.

During the year, the Chief of the Division paid a visit to the Territory of Papua and New Guinea at the request of the Administrator, who was seeking advice on plant problems. Later, he attended the Second Conference of the Food and Agriculture Organization of the United Nations at Copenhagen, as one of the delegates representing Australia. Dr. C. Barnard visited Norfolk Island at the request of the Department of External Territories, to advise on the rehabilitation of agriculture and horticulture.

Once again it is a pleasure to acknowledge the ready assistance and co-operation which have been forthcoming from the authorities in all States in the wide range of investigations in which the Division is engaged. It would be invidious to make any special reference to this assistance, but without the help that the Division has received, the investigations could not have been so far advanced. It is desired, however, to refer especially to the help given by State Departments of Agriculture and by Universities.

2. *Pasture Investigations.*—(*i*) *Canberra, A.C.T.*—(1) *Management of Sown Pastures.*—(*a*) *Phalaris-subterranean clover.*—Following a demonstration that a system of rotational grazing at fixed intervals gives no advantage over continuous grazing on a *Phalaris*-subterranean clover pasture, work has been continued to determine whether any system of deferred grazing might be advantageous. Both in 1945 and 1946 dry weather led to cessation of growth before the full growth cycle of the *Phalaris* was complete, and in neither season were inflorescences produced. It is evident that the unreliability of the winter and spring rainfall in Canberra will necessitate the adoption of a technique not depending on an unbroken and full-length growing season by *Phalaris*. Work is being initiated in 1947 using a different approach to this problem.

(*b*) *Wimmera ryegrass-subterranean clover.*—A number of experiments were commenced in 1946 to determine the factors influencing the survival of Wimmera ryegrass under grazing at the Dickson Experiment Station. The main experiment will determine the effect of survival and production in ensuing years of Wimmera ryegrass-subterranean clover so treated as to vary the density of the population of both the ryegrass and the subterranean clover, the amount of litter on the surface at the commencement of the season, and the incidence of autumn cultivation. Subsidiary experiments have given useful preliminary data on the effect of water supply, nitrogen supply, and competition by subterranean clover on the development of Wimmera ryegrass in an old sward.

(2) *Management of Natural Pasture.*—A large-scale grazing trial to be conducted in co-operation with the New South Wales Department of Agriculture at its Experiment Farm at Trangie, will commence in August, 1947. This farm lies on the western boundary of the wheat belt in north-west New South Wales where much of the perennial cover has been appreciably reduced by overgrazing. The experiment area was contour-surveyed in October, 1946, and a soil survey made in January, 1947. Commencing in December, 1946, a detailed vegetation survey was made; at the time, severe drought conditions were being experienced, and the record of basal area of perennial grasses thus provided an excellent account of the permanent components of the ground flora.

(3) *Mineral Nutrition Investigations.*—Eleven trials were established during the autumn of 1946 on the Southern Tablelands of New South Wales. The centres were selected to represent a wide range of soils of different origin at Young, Booroowa, Crookwell, Taralga, Goulburn, and Tarago. These trials were designed to test the effect of all known essential major and trace elements on the establishment and yield of a *Phalaris*-subterranean clover pasture. The design included a comparison of various rates and frequencies of applications of superphosphate, but the rainfall during the growing season in 1946 was low and growth generally was poor. Nevertheless, the *Phalaris* established well, while the clover set sufficient seed for re-establishment in 1947. Responses to superphosphate

were obtained where the rainfall conditions were most favorable. Though no responses to trace elements were obtained, results from pot cultures indicate that in seasons with better rainfall responses to molybdenum are likely in certain of the soils. Responses to nitrogen were common, indicating the need for developing legumes on these soils.

Work at the Dickson Experiment Station continues to demonstrate the lack of response by pasture species to superphosphate. The poor or mediocre development of lucerne at the Station has been under inquiry for some years, and evidence is now forthcoming that the abnormal development is due not to any deficiency of major or trace elements, but to an excess of manganese in the soil. Analyses of lucerne have given values for manganese content some six-fold greater than those usually recorded for the species. It has been demonstrated in pot cultures that the raising of pH and of the calcium level by the application of lime will reduce substantially the uptake of manganese, and thereby permit a more normal development of the lucerne.

Pot culture studies on the mineral status of savannah woodland and dry sclerophyll forest soils from the Canberra district are continuing; a relationship between the climax vegetation and the mineral status of the soils is apparent.

(4) *Pasture Establishment under Cover Crops.*—A cover crop trial sown in 1945 with varying rates and various methods of sowing cereals, pasture species, and fertilizer was repeated in 1946. The experiment has been confined in these first two years to the use of Wimmera ryegrass as the sown pasture grass, but results indicate that the method of sowing the cereal can be so varied as to warrant the investigation of the possibility of establishing *Phalaris tuberosa* under a cover crop. This perennial grass is costly to establish, and any method which enabled a cereal crop to be harvested during its establishment year would be extremely useful.

(5) *Species and Strain Investigations.*—The comparison continued of the introduced perennial grass, *Festuca Mairei,* and the standard perennial pasture species of this area, *Phalaris tuberosa,* each in a sward with subterranean clover under grazing. Results are disappointing. The *Festuca* has shown heavier summer mortality than the *Phalaris* and yields have been significantly lower. In March, 1946, the yield of *Phalaris* was approximately double that of the *Festuca,* while in December, 1946, it was almost four-fold greater. The indications are that *Festuca Mairei* is inferior to *Phalaris tuberosa* as a perennial grass under Canberra conditions.

Preliminary work on a number of species and strains of other pasture plants is in progress at various points, some in conjunction with the Plant Introduction Section.

(6) *Danthonia Investigations.*—Work is continuing to determine economic means of artificially establishing *Danthonia* pastures. The two principal aspects under inquiry are the factors affecting the germination of the seed under both laboratory and field conditions, and means of securing naked seed by mechanical treatment with minimum breakage of the caryopses. It is hoped in 1947 to harvest a sufficient bulk of seed to enable semi-commercial tests to be made of methods of seed treatment and field establishment.

(7) *Toxaemic Jaundice.*—Co-operative work with the Division of Animal Health and Production and the Division of Soils on the factors influencing the geographic and seasonal outbreaks of toxaemic jaundice in New South Wales is being continued. Surveys of the botanical composition of the pasture on a number of selected properties in the Murray Valley and Woodstock districts are being made at regular intervals. Four such surveys have been completed. The abnormally dry winter and spring of 1946 prevented normal pasture growth on most of the properties surveyed. No obvious relationship has yet been observed between the disease and the botanical composition of the various pastures surveyed. Copper content of all pasture species has shown a general decrease from September, 1945, to September, 1946, but full interpretation of the results will depend on the accumulation of further botanical and analytical data during 1947.

(8) *Ecology of Native Pastures.*—A commencement has been made with the survey of the natural vegetation and pastures of a section of the tablelands and slopes of New South Wales. Only preliminary data have yet been collected.

A detailed study of the ecology of the *Stipa-Danthonia* pastures of the Canberra region is being undertaken. The first phase is a study of the phenology of these pastures based on fortnightly records of the incidence and state of growth of the various contributary species. A study of the degeneration of the climax grassland of this area under the influence of grazing is in progress; it is based on the examination, by the line intercept method, of a large number of pastures varying from those which have been fully protected for a number of years to those suffering severe overgrazing.

(ii) *Regional Pasture Laboratory, Deniliquin, New South Wales.*—The year's activities have been directed to the physical development of the Falkiner Memorial Field Station and to the developmental investigations to define the field station environment. A research programme has been developed, as a result of empirical trials which have been laid down and completed during the year. The first building contract has been completed, and the plans and working drawings for the main laboratory buildings are well advanced.

(1) *Developmental Works.*—Four brick cottages and a field laboratory-workshop at the Falkiner Memorial Field Station and the preparation rooms of the main laboratory in Deniliquin have been completed. These rooms provide temporary laboratory accommodation.

The internal irrigation channels of the Field Station were constructed during September-December, 1946. Fifty-five acres of land are now under irrigated pasture and fodder experiment, with a further area being prepared for planting in the spring of 1947.

In 1946, preliminary trials with summer fodders under irrigation were made on rice stubble at Wakool on Noorong clay loam and on Mundiwa clay loam at Wariston Station. Yields of up to seven tons per acre of dry material were obtained on the rice stubbles with two acre feet of irrigation water, and 2 cwt. per acre of sulphate of ammonia. The yields on the Noorong clay loam after rice were appreciably better than on the Mundiwa clay loam.

Tests were also made of summer-growing perennial grasses. Rhodes grass (*Chloris Gayana*) and *Paspalum dilatatum* can be readily established on the "difficult" clay loams, and they provide good yields during the first two summers.

A comparison of the two winter growing pasture mixtures—Wimmera ryegrass-subterranean clover and *Phalaris tuberosa*-subterranean clover, was initiated on the Cobram-Katunga soil series at Carrigan Park. The clover established poorly, but both grasses established well. This trial will continue.

Infiltration tests on a number of representative soil types under varying conditions are in progress. Improvement in brairding of pasture plants on rice stubble compared with virgin soil was not accounted for by any modification of infiltration rates.

A vegetative survey of the Field Station was completed during the year. This has been linked with a detailed soil survey. Assistance has also been given to

the Division of Animal Health and Production on toxaemic jaundice investigations at their Barooga Field Station.

(iii) *Institute of Agriculture, Nedlands, Western Australia.*—(1) *Ehrharta Grazing Trial.*—A comparison of continuous and six-weekly rotational grazing of a pasture mixture of *Ehrharta calycina* and Dwalganup subterranean clover by Merino sheep was laid down in 1943 on Karrakatta sand series at the Institute of Agriculture, Perth. The pasture has been stocked at the rate of four sheep per acre and has been fertilized annually with superphosphate, potash, and copper sulphate, and more recently with cobalt.

There have been no important differences between the yield of pasture or sheep liveweights on the two grazing treatments. Wool production has also remained unaffected. On both treatments the percentage of *Ehrharta calycina* has declined, but the decline has been more rapid on the continuous grazing plots. During 1945, the grass virtually disappeared under continuous grazing, while a small percentage remained in the rotational grazing until 1946.

(2) *Wimmera Ryegrass Trials.*—The disappearance of Wimmera ryegrass in admixture with subterranean clover has become important in Western Australia partly because of the absence of a suitable associated perennial grass. The effects of various cultivation practices, available nitrogen, interspecific competition, and seed rates both in the first and subsequent years are being examined. No adequate explanation of the decline has yet been found and the investigations will be continued.

(3) *Mineral Deficiency Studies.*—Pot culture and field trials on mineral deficiencies of the coastal sandy soils have been continued. Phosphate and potash deficiency and responses to molybdenum have been recorded in pot culture tests with subterranean clover on yellow sands from the Gin Gin district. Cobalt sulphate, in field plots of subterranean clover at the Institute, has increased the cobalt content of the plants without any measurable change in the yield of dry matter.

(4) *Pasture Trials Related to the "Infertility" Problem in Sheep.*—These studies form part of a co-operative programme with the Department of Agriculture, Western Australia, and the University of Western Australia.

(*a*) *Grazing trials.*—Two experiments on "affected" country were initiated in 1945 to examine the effects of two contrasted pastures on the incidence of infertility, dystokia, and prolapse. The pastures were: (i) subterranean clover dominant, and (ii) oats plus Wimmera ryegrass. For each treatment a paddock of 100 acres was used and the rate of stocking maintained at about 1 sheep per acre. Unmated two-tooth Merino ewes were employed in each trial, those at Wandering being from "healthy" country and those at Narrogin from "affected". Pasture samples were collected at fixed dates throughout the season, chiefly for the determination of botanical composition. Lambing data were collected in detail.

Results to date indicate that young sheep from "healthy" country remain fertile after a few months' grazing on green subterranean clover. Further, by reducing drastically the percentage of subterranean clover in the pasture, previously unmated young ewes from "affected" country are less affected by dystokia than on subterranean clover dominant pasture. A further field trial is being initiated.

(*b*) *Plant nutrition studies.*—The effect of all known nutrient elements on the potency of Dwalganup subterranean clover is being examined. The results, as yet incomplete, suggest no effect of nutrient status of the plant on oestrogenic content. The work has been supplemented by samples collected from light and heavy textured soils. The assay results have been variable and so difficult to interpret that the work is being repeated in 1947.

(*c*) *Strain trial.*—Sixteen strains of subterranean clover were grown on an affected property in 1946 for determination of differences in potency. This work, also, is being repeated, since an unexpected deficiency (probably zinc) precluded the collection of sufficient material for assay purposes.

(5) *Wongan Hills Grazing Trial.*—This comprehensive experiment, the objectives of which were outlined in last year's report, was commenced in 1946 and is being continued.

(iv) *Armidale, New South Wales.*—(1) *Grazing Management Studies.*—Experiments to study the effect of different grazing treatments on natural pasture in the New England district and on parasitism in the grazing sheep, have been planned in co-operation with the Division of Animal Health and Production. The experiments involve a comparison of: (*a*) different rates of stocking, (*b*) continuous versus rotational grazing, and (*c*) the effect of different sizes of flock, and a study will be made of grazing treatments on: (*a*) parasitic infection, (*b*) wool production, (*c*) liveweight and growth of sheep, (*d*) yield and botanical composition of the pasture, and (*e*) chemical composition of the pasture.

A botanical survey of the sites for the experiments has been made, and the plots arranged to ensure reasonable uniformity of pasture types on each treatment.

(2) *Species Trials.*—A sowing of 75 forage species, mostly legumes and grasses, on each of the three main soil types in the district, was made in the autumn of 1946. The object of the trial is to determine the most suitable species for the New England environment, particularly with regard to their capacity to provide forage during the critical winter months. In these initial tests the species have been grown in inter-cultivated rows.

In the first year *Phalaris tuberosa,* sheep's burnet (*Poterium Sanguisorba*), and several varieties of lucerne gave the best overall performance. Wimmera ryegrass, prairie grasses, sheep's burnet, hairy Peruvian lucerne, and several varieties of subterranean clover gave the best winter production. Various *Agropyron* spp., *Phalaris tuberosa,* some *Bromus* spp., red clover, and two *Melilotus* spp. made best summer growth.

(v) *Cooper Laboratory, Lawes, Queensland.*—During the past year, facilities for pasture research at this Laboratory have been improved by the erection of a soil store, dehydrator room, sorting laboratory, and garage-workshop.

(1) *Lucerne-Rhodes Grass Pastures.*—Grazing was commenced in the spring of 1945 on a beef-cattle grazing experiment in which comparisons are being made between two strains of Rhodes grass, each sown in swards with and without lucerne as the pasture legume. Each treatment is replicated three times, and each plot is subdivided into five sub-plots to permit rotational grazing. The value of each pasture is being assessed by liveweights of the steers, and the yield and chemical and botanical composition of the pastures.

For the fifteen months, the steers have made better gains in liveweight where lucerne is present in the mixture. There is some indication that standard commercial Rhodes grass gives better liveweight increases than the introduced Kenya No. 1 strain, though the yield of dry matter from the latter is the greater. During the winter period the grazing animals lost weight in all pastures, the live weight loss being the same for all treatments. During this winter period the yield of lucerne in the mixtures was less than ¼ cwt. per acre.

Observations on a number of lucerne strains, including "creeping" types, planted in associated with Kenya No. 1 Rhodes grass and commercial Rhodes grass, show that "Hunter River lucerne" has been outstanding in yield and survival.

(2) *Row Pastures.*—The experiments reported in the 20th Annual Report on row pastures using *Paspalum scrobiculatum* and *Medicago sativa* alone and in combination have been continued. Rows of *P. scrobiculatum* at 3-ft., 4-ft., and 5-ft spacings have been compared with swards in the presence and absence of applied sulphate of ammonia at 4 cwt. per acre, and of lucerne. All row treatments are superior to swards. In the absence of the sulphate the highest yield of grass alone is obtained from 4-ft. rows, but with sulphate the 3-ft. rows give slightly higher production per acre.

The total yield per acre from alternating rows of *P. scrobiculatum* and lucerne is less than from grass alone over a three-year period—i.e. gross production of dry matter is greater from *P. scrobiculatum* than from lucerne. There are, however, important differences in the periodicity of the production between the two species.

Earlier observations that lucerne grown in alternating rows exerted a serious competitive effect on the grass rows have been confirmed. Studies indicate that root competition is the significant factor; lucerne in rows develops a lateral spreading root system which, during the second and subsequent years, penetrates through the root zone of the adjacent *P. scrobicolatum* and may attain a lateral spread of 8 ft. on each side of the row. The preliminary evidence available indicates that the competition is primarily for available soil moisture supply.

(3) *Cattle Pastures.*—Experiments at Rodd's Bay Station, near Bororen, Central Queensland, have demonstrated that light surface cultivation increases the yield of spear grass (*Heteropogon contortus*) pastures. In one year the average increase was 26 per cent., and the total yield equal to that from plots top-dressed with mixed fertilizer (200 lb. sulphate of ammonia, 4 cwt. superphosphate, and 3 cwt. muriate of potash). The increase is thought to result from better penetration of water in cultivated land. The results from one year's tests will be checked.

In field experiments and/or in pots phosphatic fertilizers have increased the yield of lucerne and of Townsville lucerne on Rodd's Bay soil. In one experiment, Townsville lucerne yielded 7 cwt. per acre, this being 21 per cent. (dry weight) of the pasture. There is some indication that additional benefit was obtained from applications of potash. Lime did not improve yields in the first year, and Townsville lucerne did not respond to applications of trace elements. New experiments will measure yields with varying amounts of phosphate and potash. Among introduced species broadcast on surface cultivated spear grass pasture, *Phaseolus lathyroides* and *Stylosanthes gracilis* gave encouraging results in the first year.

An experiment to measure the yield and botanical and chemical composition of spear grass pasture, at Calliope Station near Gladstone, Central Queensland, under the present form of management, was commenced in January, 1947. It is designed to give basic information about these pastures.

The effect of burning on the botanical composition of native pasture is being studied at Lawes. Present indications are that *Heteropogon contortus* is favoured by burning, while *Bothriochloa decipiens* and *Eremochloa bimaculata* are suppressed. The experiment will be continued for several more years.

(vi) *"Gilruth Plains", Cunnamulla, Queensland.*—(1) *Investigations in the Semi-arid Summer Rainfall zone.*—(*a*) *Grazing management studies.*—A continuation of drought condition at Gilruth Plains prevented the resumption of stocking on the Mitchell grass grazing experiment, in which the effect on a Mitchell grass pasture and on the grazing sheep of light, medium, and heavy stocking under both continuous and rotational grazing, are being measured. However, completion of the laboratory work on the samples collected before the discontinuation of stocking on account of drought in October, 1945, enables additional data to be presented.

(*b*) *Total available forage.*—At the final sampling, the total forage available under all grazing treatments was at a low level (from 0.3 to 1.8 cwt. of dry matter per acre). Under continuous grazing the amount of forage available was the same at both light and medium rates of stocking, but under heavy stocking it was significantly less. Under rotational grazing there were no differences in the amount of forage available at any rate of stocking.

(*c*) *Botanical composition of the pasture.*—The most important real effect of the grazing treatments on the botanical composition was the decrease in the proportion of Mitchell grass under the heavier rate of stocking, particularly with rotational grazing involving summer grazing and winter spelling. Some high figures for the relative amounts of miscellaneous (herbage) species were recorded at the later samplings, but these were from rotational grazing treatments that were low in other constituents and which had been unstocked for some time prior to sampling.

(*d*) *Chemical composition of pasture.*—No changes in chemical composition of the pasture under the different grazing treatments have been recorded. The different species groups (i.e. Mitchell grass, other grasses, miscellaneous species, legumes, and inert material) have, however, varied markedly in chemical composition. The miscellaneous (herbage) species have shown a potentially high nutritive value, being high in protein, calcium, and phosphorus, and low in cellulose.

(*e*) *Wool production.*—The sheep on the experiment have been shorn five times. The mean weight of greasy wool produced per head was 10 lb. 2 oz. (valued at 13s. 1d.) with one sheep to 7.5 acres under continuous grazing, and 10 lb. 7 oz. (13s. 7d.) under rotational grazing. At one sheep to 5 acres the figures were 10lb. 3 oz. (13s. 1d.) and 9 lb. 9 oz. (11s. 10d.) respectively, and at one sheep to 2.5 acres, 9 lb. 4oz. (10s. 9d.) and 8 lb. 8 oz. (10s. 5d.).

Net cash returns per head show a greater disparity between treatments because of the need to provide more supplementary feed to the groups on the heavier rates of stocking.

(2) *Regeneration of Natural Semi-arid Pastures.*—An experiment to test methods of re-establishing Mitchell grass on country from which it has disappeared, but on which reasonably good seed-bed conditions are available, has been started. The seeding methods involved include broadcasting and sowing with a seed drill, the latter using different row spacings and drill width spacings.

3. *Weeds Investigations.*—During 1946, the weeds work was divided into two sub-sections—physiology and ecology. The Physiology Sub-section is concerned with the physiology and biochemistry of plants as related to the penetration and translocation of plants poisons and with the development of more efficient herbicides. The Ecology Sub-section is concerned with the determination of the ecological factors concerned with the invasion and establishment of weeds, particularly in grassland. In particular, this sub-section is concerned

with research into the autecology of individual weeds, the agronomic factors relating to the infestation of crop lands, and the testing of herbicides in the field.

At Cassilis (New South Wales), the fundamental relationships between grazing and weed infestation are being investigated. A preliminary survey of the Liverpool Plains was made in November, 1946. Sir Frederick McMaster has kindly offered the use of land at "Dalkeith".

In view of the successful results reported by overseas workers with growth-regulating compounds, it was decided that an early evaluation of these substances as herbicides in Australia was desirable. A large number of small-scale tests were laid down in Victoria, New South Wales, and Canberra on a variety of plants. The results have been published in Plant Industry Divisional Report No. 1. In addition, co-operative tests are being conducted with the Department of Lands and Survey in Victoria, and with the Australian Forestry Bureau in Canberra. Limited tests have also been conducted with carbamates which are reported as being selective on monocotyledons.

(i) *Hoary Cress* (*Lepidium Draba*).—Preliminary trials with growth-regulating substances at Wagga towards the end of 1945 were unsuccessful, as the plants were too mature at the time of spraying. An experiment was initiated at Murtoa, Victoria, during August, 1946, using aqueous sprays of growth-regulating substances on hoary cress in a wheat crop. The top growth of cress was completely killed by both Methoxone and 2, 4, 5-T.C.P., the latter substance apparently being effective at lower concentrations than the Methoxone. While it is too early to forecast what permanent effects the applications will have on the weed, the reduction in cress-wheat competition by the Methoxone treatments significantly increased wheat yields. 2, 4, 5-T.C.P., although more active on hoary cress than Methoxone, was less selective in its action and significantly depressed wheat yields. A marked correlation was found between initial cress density and grain yields.

(ii) *Nutgrass* (*Cyperus rotundus*).—Experiments at "Riverton", Tenterfield, with soil fumigants showed that in a dry consolidated silty soil, injections of chloropicrin at rates of 500 and 1,000 lb. per acre were successful in killing nutgrass, and it is considered that lower rates of application may be effective. D-D (a mixture of dichloropropane and dichloropropylene used successfully in wireworm control) was effective at 1,000 lb., but not at 500 lb. per acre. Additional experiments are in progress using other fumigants and different methods of soil treatment before and after injection. At Canberra limited tests with growth-regulating compounds showed that 1 per cent. Methoxone dust at 500 lb. per acre was the most effective treatment.

(iii) *Skeleton Weed* (*Chondrilla juncea*).—Growth-regulating substances have given variable results on this species. Although some plants have been killed to appreciable depths, the roots of other plants in the same plots have been killed to a few inches only.

(iv) *Bindweed* (*Convolvulus arvensis*).—Applications of growth-regulating compounds at the rate of 1 lb. per acre have given a 90 per cent. kill. As some plants recover, respraying will almost certainly be necessary for the complete eradication of this species.

(v) *Lawn Weeds.*—Waterweed (*Hydrocotyle tripartita*), a serious weed of golf and bowling greens, and dandelion (*Taraxacum officinale*) have been controlled by applications of Methoxone or 2, 4-D at the rate of 1lb. per acre. Cat's ear (*Hypochaeris radicata*) a common flatweed of turf, and wild sage (*Salvia verbenacea*), a weed of poor turf, have been controlled by applications of the same substances at 2½ lb. and 5 lb. per acre respectively.

(vi) *Annual Cruciferous Weeds.*—Several annual and biennial species of the Cruciferae have been killed by light applications of growth-regulating substances. Among the weed species killed were wild turnip (*Brassica Tournefortii*), Buchan weed (*Brassica adpressa*), shepherds' purse (*Capsella Bursa-pastoris*).

(vii) *Mistletoe Control.*—Some attention has been given to the control of mistletoe (*Loranthus pendulus*), at the request of the Queensland Government. Somewhat promising results have been obtained but the solution of the problem is far from complete, and much work remains to be done.

(viii) *Weeds of Vegetable Crops.*—One promising application of hormone-like weed-killers is in the control of weeds in vegetable crops. In view of reports of damage to pea crops by the use of Dinoc, preliminary trials have been made on the effects of some weed-killers on peas. It has been found that while 2, 4-D sprays are detrimental to peas, sprays of 2, 4, 5-T.C.P. and 2, 4, 6-T.C.P. have little or no effect. The effects of spray adjuvants depend on their performance as wetters. Arrangements have been made for a trial of these weed-killers in weeds of pea crops.

(ix) *Mintweed.*—An experiment on the Darling Downs in 1945-46 showed that mintweed was not a serious competitor in maize, grain, sorghum, sweet sorghum, or sudan grass, in a good season and when ordinary cultivation methods are used. The experiment was repeated in the summer of 1946-47; the results confirmed the earlier finding.

Mintweed sprayed with 5 per cent. arsenic pentoxide has been completely killed, while partial kills have been obtained with Methoxone, Chloroxone, and Dinoc. The last three sprays did not kill grass species, and are, therefore, more promising than arsenic. The most effective concentrations have yet to be determined. In pot experiments, 0.5 per cent. Methoxone sprayed on the soil prevented germination of mintweed and of *Urochloa pullulans*; 0.1 per cent. Methoxone aqueous spray and 1.0 per cent. Methoxone dust suppressed mintweed germination without having much effect on the grass.

Experiments to determine the optimum and requisite conditions for germination of mintweed have been conducted in co-operation with the Queensland Department of Agriculture and Stock. Results from pot experiments at Lawes indicate that for satisfactory germination of mintweed, seed must be on or near the surface of the soil. Further trials are planned for 1947.

During 1946, several new areas of mintweed infestation were found in the Burnett and Callide watersheds. Here the weed has been spread as an impurity in crop seeds, especially in seed of white Panicum.

(x) *Physiological Investigations.*—The apparatus previously devised for determining death of tissues by means of the measurement of electrical resistance has been improved so that readings of capacitance can also be made. It has been found that, when using a probe, capacitance gives a better indication of death than resistance. The apparatus can now be used to distinguish if tissue is dead, and whether the tissue is wet or dry.

In investigations on the downward translocation of poisons in weeds, it has been found that the rapid death of leaf tissues is undesirable, with spray solutions containing arsenic pentoxide or hormone-like poisons.

In view of the importance of soil moisture in both weeds and agrostological investigations, the electrical equipment used for determining death of tissues has been modified for measurements of soil moisture, using plaster of paris blocks. The apparatus is more sensitive than, and only half as expensive as, imported soil moisture meters.

On account of the importance of surface roughness of leaves in studies of wetting, a simple interferometric method has been devised for measuring the roughness of cuticle deposits.

4. *Plant Introduction.*—(i) *General.*—The principal developments in the work of the Plant Introduction Section during the past year include:—(*a*) Continued expansion in overseas plant exchanges and in the interchange of material with Departments of Agriculture and similar organizations within Australia. (*b*) Initiation of plant introduction trials at Katherine, Northern Territory. These trials comprise pasture and forage plants, and a wide range of crop plants of possible economic value in the Territory. (*c*) Transfer of plant introduction activities in Western Australia from Muresk to the Institute of Agriculture, Perth, and the State Experiment Station at Wokalup. (*d*) Greatly extended regional trials of more promising introduced plants, largely in co-operation with other Sections of the Division and with State organizations. (*e*) Expansion in the work of the herbarium, involving routine determinations of pasture and other plants, and large additions to the collections.

There now exists a well-located chain of initial testing stations and suitable facilities for regional trials of more promising introduced species and strains.

(ii) *Introduction and Exchange of Plants and Seeds.*—During the year, 825 introductions of seeds and plant material were received from overseas countries, this being an increase of over 60 per cent. on the previous year. An approximately equal number of Australian seed samples were sent away in exchange. The introductions came from 31 countries in all parts of the world. As in previous years, pasture and forage plants constituted the largest class of introductions. Notable among these are 89 samples of vetches (*Vicia* spp.), including 52 varieties forming part of an interesting collection of forage plants received from Bulgaria. Some recently introduced varieties of vetches have shown great promise in Western Australia and elsewhere, and the extensive collections now available should make possible a fuller evaluation of the genus in Australia.

Oilseeds (122) and vegetable varieties (108) are next in importance among the classes of introductions. Technical plants introduced for trial include additional varieties of guar (*Cyamopsis*) and varieties of camphor basil (*Ocimum kilimandscharicum*).

More than 500 samples of seed have been supplied to State Departments of Agriculture and other outside bodies for trial, and many samples have been received in exchange for trial by the Section and for sending to overseas correspondents.

(iii) *Pasture and Forage Plant Trials.*—Trials of new and promising pasture and forage plants have been continued at all centres, and coincidentally strains selected as suitable for further investigation are being tested.

Particular attention is devoted at Canberra and in Western Australia to the search for self-regenerating annual and perennial grasses which might replace Wimmera ryegrass where the species is unsuccessful. Some of the species of *Bromus* show promise in this connexion, and are being subjected to critical trial. Other promising grasses which have been introduced recently include species of *Agropyron* from Canada, which are vigorous and productive at Canberra, Melbourne, and Armidale, and species of *Stipa* and other genera from Uruguay which are under trial in northern New South Wales.

In the search for grasses which might advantageously replace the native species in parts of the interior of northern Australia with a short but well-defined growing season, many species have been under trial at Katherine. Several varieties of bulrush millet (*Pennisetum typhoideum*) have been outstanding, and indicate the potentialities of this species in regions which are too dry for the grain sorghums.

In trials at Muresk some introduced strains of *Vicia* and *Lathyrus* have proved superior to the locally-grown field pea varieties in both grain and green-matter production, and they have the additional advantage of immunity to pea weevil. They are being further tested in Western Australia and at Griffith, New South Wales, where they may be of value as green-manure and cover crops.

Samples of seed of Stylo (*Stylosanthes gracilis*) have been distributed for trial in numerous localities throughout Queensland and other parts of northern Australia. The results of these trials will yield information on the regional adaptability and the climatic and soil requirements of this valuable pasture legume. The early-flowering variety of Stylo mentioned in the previous report has been further tested at Katherine, where it is of particular value because of the coincidence of its flowering period with that of the native grasses.

Some of the more recent introductions which appear promising under trial at Redland Bay (Queensland), but which must be further tested before final conclusions can be drawn, include *Stylosanthes viscosa,* several species and strains of *Arachis,* a species of *Desmodium,* and the kudzu vine (*Pueraria Thunbergiana*).

Further work is in progress with varieties of pigeon pea (*Cajanus Cajan*) and cowpea (*Vigna unguiculata*). A feeding trial at Canberra indicated that the leaves and pods of the former can be used as a maintenance ration for sheep in drought areas, whilst an extensive test of cowpea varieties has been conducted at Katherine.

(iv) *Trials of Vegetable Oil Plants.*—Vegetable oil plants under trial at one or more centres include varieties of soybean, linseed, sunflower, peanut, castor bean, safflower, rapeseed, sesame, *Perilla,* and *Lallemantia.* Importance is attached to these crops because of the dependence of Australia on overseas supplies, and because vegetable oils are among the few potentially valuable crops for the Northern Territory.

Varietal trials of soybeans have been conducted at several centres from Victoria to the Northern Territory. Preliminary indications confirm previous experience of the great range of varietal response to different conditions, and indicate the need for much more work before the full potentialities of the crop can be assessed and suitable varieties selected for each locality.

Climatic conditions in southern Queensland were very unfavorable to the growth of linseed, and yields were much lower than in the previous year. Further varietal trials are in progress at several localities.

At Katherine, investigations are in progress to determine the potential value of various vegetable oil crops, both under irrigation and under natural rainfall. Some of the Indian varieties of rapeseed, especially varieties of "Raya" (*Brassica juncea*) gave high yields in a preliminary trial under irrigation, and were conspicuously vigorous and healthy. Further trials of spacing and time of sowing are in progress. A variety of sesame gave a seed yield averaging 6.6 cwt. per acre from a trial plot grown under natural rainfall, compared with average yields of 2 to 4 cwt. from commercial plantings elsewhere.

(v) *Trials of Technical and Miscellaneous Plants.*—Trials of barley varieties were continued on a restricted scale at Muresk (Western Australia). Six introduced varieties have outyielded the local control variety in each of the last three years, and appear to warrant extensive commercial trial.

Work with guayule rubber (*Parthenium argentatum*) will be discontinued at Canberra after the present season, as the growth at this centre is much inferior to that elsewhere. The experiments conducted over the last three years have furnished information on the effect of periodic cutting on the growth and rubber content of the plant.

A variety of guar (*Cyamopsis tetragonoloba*) has grown well on the black soils at Lawes (Queensland) and further varieties have been introduced for trial. This plant is receiving much attention elsewhere as a source of mucilage for use in the manufacture of paper, ice cream, and other products.

Other technical plants under trial include varieties of yam bean (*Pachyrrhizus* spp.) and of camphor basil (*Ocimum kilimandscharicum*).

(vi) *Herbarium.*—Since October, 1946, when a full-time systematic botanist was appointed to the staff, over 1,500 specimens have been determined. The majority of these were plants collected by members of the Agrostology Section while on field work in connexion with pasture surveys and investigations in Queensland and New South Wales. Other specimens were received from the Northern Territory, South Australia, Victoria, and Tasmania.

Most of this material has been mounted and placed in the herbarium, which has increased during the year by more than 1,500 specimens, bringing the total to 13,387. Additions include a collection of 155 British grasses received from the Herbarium of the Royal Botanic Gardens, Kew, England, which will be of particular value in checking the identity of some of the alien grasses now established in Australia, and of species introduced for trial. Other additions include exchange specimens from Sweden and Portugal, and a parcel from Mr. C. T. White, Government Botanist of Queensland.

5. *Wheat—Take-all of Wheat.*—The results of both pot and plot experiments show that if the soil and climatic conditions are suitable for satisfactory development of the wheat plant, take-all will be of little or no economic importance. Conversely, if conditions are unfavorable the disease will significantly decrease the yield of grain. The conditions may be inherent in the soil and climate of the locality, or they may be induced by improper management that has resulted in temporary soil exhaustion. The means whereby fertility can be restored are well-known and widely practised.

The exact role of the organism, *Ophiobolus graminis,* in causing economic loss has for many years been uncertain. However in all experiments made since 1938 the environmental factor that determined whether plants produce empty heads was unavailability of plant food. The soil and climatic factors influencing availability are different in most localities and seasons. For practical purposes, the organism may be assumed to be in the soil of every wheat field. But it will not cause appreciable loss in yield of grain unless and until the plant is seriously weakened physiologically by any of several conditions that make soil nutrients unavailable for its use. The disease is, therefore, a good indicator of the unsuitability of soil and climate for economic wheat production. Some of the soil conditions can be and are controlled and corrected by man.

6. *Fruit Investigations.*—(i) *In Tasmania.*—The investigations dealing with the physiological disorders of apples and pears in the orchard and the disorders of these fruits during storage, are still suspended. The officer responsible for these studies has been seconded to the Department of Commerce and Agriculture for the 1947 export season, for duty in the United Kingdom where he will examine and report on the condition of Australian apples and pears reaching the English market.

(ii) *At Stanthorpe.*—A general account of the scope and purpose of the investigations at Stanthorpe which concern apple and pear rootstocks, was given in the Council's *Journal* for May, 1938, and results obtained during the first ten-year period were summarized in the 18th Annual Report of the Council (p. 10, 1944).

Routine operations, growth measurements, and records of yield and behaviour of the different apple and pear stock-scion combinations under trial in nursery and orchard plantings have been continued. Multiplication of the Merton apple rootstocks Nos. 793 and 789, which gave the best results in nursery trials previously reported, was continued and a few parcels of these stocks were released during the winter of 1947. Further supplies should be available during 1948.

In another nursery trial a locally selected apple rootstock named 54 has produced more vigorous and healthier trees than the ordinary Spy stock. Nursery trials have also shown that Jonathan scions on Merton stocks 778 and 779 and Zuccamaglio Reenette which are all immune to woolly aphis, grow more strongly than on Spy stock. Additional types of rootstocks immune to woolly aphis and obtained by crossing Spy with Malling stocks have been obtained from East Malling, and are being propagated for trial under Stanthorpe conditions.

A further 10 acres of land have been cleared and prepared for planting during the year, partly for the establishment of a further orchard trial including Merton stocks 793 and 789, and partly for nursery and multiplication work. This extension will increase the area of experiment plantings to 20 acres. A dam to hold 250,000 gallons of water has been constructed, a tractor acquired, and several other capital improvements affected.

7. *Drug Plant Investigations.*—The general nature and scope of these investigations was summarized in last year's report. The main items of study have continued to be: (i) the study of *Duboisia spp.* as sources of hyoscine and atropine; (ii) the study of varieties of opium poppy as sources of the opium alkaloids; and (iii) the systematic search for sources of pharmacological and insecticidal substances in native plants.

(i) *Duboisia Spp.*—The results of cultivation and harvesting trials conducted at Nambour (Queensland) and Canberra (Australian Capital Territory) were reported in the Council's *Journal* for November, 1946, p. 359. The intensive work in the plots at Nambour is being concluded, as they have now served their main purpose. In the coming year the results of differential cultural treatments will be determined by periodic observation only, and the plots will then be abandoned. By courtesy of the Department of Agriculture and Stock of Queensland, a small plot of trees of selected types will be maintained at Nambour. Other trials will be conducted at Canberra in future. Progeny trials have shown that lines can be selected which combine the best field characteristics (high leaf yield per acre and hardiness) with a consistently high yield of alkaloid in pure form in both *D. myoporoides* and *D. Leichhardtii.* Selection is continuing from the best types in both species.

Investigations into the synthesis of alkaloids in the Solanaceae have been continued, using grafts between *Duboisia* spp. and other Solanaceous plants (tomato and tobacco). Results indicate that the alkaloids or precursors of them are synthesized in the roots and translocated to the leaves. These results were reported in detail in the *Australian Journal of Science,* August, 1945, and August, 1946.

An experiment has been conducted to trace the appearance and identity of alkaloids in young *Duboisia* seedlings. It was found that hyoscine appears first in the young plant, being present to about 1 per cent. at the six-leaf stage. Hyoscyamine appears only

after some months' growth. This work is reported in the Council's *Journal* for August, 1946, p. 295. The need for more detailed chemical investigation of certain *Duboisia* samples is recognized. An improved assay for hyoscine and hyoscyamine in *Duboisia* leaf is in the course of preparation.

(ii) *Opium Poppy* (*Papaver somniferum*).—Investigations were concerned this year, solely with the trial of different varieties and the breeding and selection of types most suited to high morphine production under Australian conditions.

The breeding and selection programme, commenced in 1944, aims to combine the most desirable characters of promising varieties. Eight hundred single plants were grown of a cross between one variety which is characterized by high morphine content but unsatisfactory vegetative growth, and another in which the yield of dry matter is high, the capsules large and indehiscent, and the straw stout. Some 65 of these individual plants were assayed and twenty selected for further trial. Morphine figures were low compared with previous years but compared favorably with those of the high morphine producing parent. Progress is slow, and only partial success has so far been obtained in satisfactorily combining all the desired characters. Crosses between other varieties have been made on a smaller scale with the same objective and so far with somewhat comparable results.

Variety trials were conducted both at Canberra and Griffith of a number of varieties and lines, the latter being from a cross between two varieties in the fourth generation, and some outcrosses from another variety. In all, 48 varieties and lines were tested. Of these, 31 were selected for assay on the basis of field performance. Morphine percentages ranged from 0.1 per cent. to 0.53 per cent., and yields from 0.34 to 2.3 lb. per acre. All morphine figures were generally lower than in previous years. The most promising varieties and lines were selected for further trials during the coming season.

(iii) *Native Plants as Sources of Medicinal Drugs and Insecticidal Substances.*—The search for sources of supply of pharmacological and insecticidal substances in native plants, which was commenced in a systematic manner during 1944-45, has been continued. During 1945-46 survey work was mainly concentrated in North Queensland; during the past year, survey and sample collection has been undertaken mainly in the south of that State. Several hundred spot tests for alkaloids and other substances were made on samples collected. From these results, species were selected for further examination by the Department of Physiology, University of Melbourne, which has continued to co-operate in this project, and by the Division of Industrial Chemistry of the Council. The co-operation of the Department of Physiology of the University of Queensland in the testing of samples has also been continued, and during the year the Departments of Chemistry at both the Universities of Melbourne and Sydney have collaborated in the examination of samples.

Over 100 bulk samples were despatched to various investigators. During February, 1947, a conference was held in Melbourne under the aegis of the Council; the various collaborators in this work were present as were representatives of the Departments mentioned, a member of the staff of the Forestry Department of New Guinea, and of the Department of Chemistry of the University of Western Australia. As a result a firm basis of co-operation and collaboration was established between the research workers of the Council and of the various Universities interested in the chemistry of native plants. A compilation of all published and reported references to the medicinal and poisonous properties of Queensland plants has also been completed. It includes reported and suspected, as well as proven, properties of native plants and it covers aboriginal lore and bushman's remedies, pastoral experience as well as scientific reports.

Mention might be made of one particular substance which is the subject of present investigation. Rutin, a flavonal glucoside, which has recently assumed clinical importance for the reduction of capillary fragility and the prevention of capillary haemorrhages, occurs in *Eucalyptus macrorrhyncha*, and preliminary information suggests that this species may provide a very good source of supply. A survey is, therefore, being made to determine the variation in rutin content in this species within its geographic range, and with seasonal conditions, &c. Allied species of eucalypts are also being tested for the presence of this substance.

8. *Tobacco Investigations.*—(i) *Visit Abroad.*—During the year, flue-cured tobacco-growing areas of the United States of America, Canada, and New Zealand were visited by the officer in charge of the Section. Particular attention was given to research programmes and objectives, with a view to formulation of a programme of work suitable for Australian conditions. The report stresses the necessity in Australia for adaptation of the tobacco plant and its environment in order that quality and yield may be improved. In Australia, climates and soils differ from those used in United States of America, Canada, and New Zealand, and different procedures should, therefore, be followed. A most important feature of the Australian environment is unreliability of rainfall, a factor responsible for many of the difficulties associated with tobacco production. Adaptation to, or avoidance of, this factor is essential for stability within the industry. By comparison with the countries visited, the proportion of good quality leaf produced in Australia is low and the yield per acre uneconomic.

In Australia, seasonal conditions are such that irrigation is essential for tobacco production. In some districts it supplements rainfall, while in others it supplies the full water requirements of the plant. This necessary departure from overseas practice means that flue-cured tobacco is being produced under new conditions for which appropriate production procedures and suitable varieties have not been determined. Results obtained by growers so far are promising, but much work remains to be done before the economic possibilities of the industry on the new basis can be assessed. The primary objectives of a programme of research and experimentation for Australia should be to determine the suitability, for flue-cured production, of areas where conditions generally are favorable and full water requirements can be supplied, if necessary, by means of irrigation; to develop varieties and strains better adapted to the environment, and having qualities acceptable to buyers; to control diseases and to incorporate disease resistance, when required, in acceptable varieties; to determine water requirements of tobacco and the effect of water on quality; and to determine procedures for the maintenance of soils under irrigation.

The recommendations of the report have been adopted and a five-year programme of work on diseases, chemistry, physiology, varieties, and agronomy, has been approved. Field work will be undertaken in co-operation with the States on tobacco experiment stations.

(ii) *Conference of Commonwealth and State Tobacco Officers.*—The eleventh conference was held at Brisbane on the 3rd and 4th June, 1947. The main object of the conference was to define programmes of work for the next five years. Experiment stations on which co-operative work can be undertaken, are to be established at Myrtleford, Victoria, in the Queensland-New South Wales border district, and in North

Queensland. At Manjimup, Western Australia, the work on the existing experiment station is to be extended.

9. *Vegetable Investigations.*—(i) *Potatoes.*—Work on combining resistance to the potato viruses A, X, Y, and leaf roll, in hybrids of good agronomic quality is being continued. Study of the reactions to virus Y in hypersensitive hybrids has been carried a stage further by comparative work with virus C, a strain of virus Y. A paper on this aspect was published in the Council's *Journal* for August, 1946, p. 273. The development of resistance to the leaf roll virus in potato has proved difficult, but work done recently indicates the possibility of developing highly resistant hybrids.

Over the last few years the potato-adapted strain of the tomato spotted wilt virus has become serious in potato crops in certain highland districts of Australia. A survey of the Canberra potato hybrids under conditions of severe field infection has shown at least half of them to be immune or highly resistant to infection. Further work on resistance to spotted wilt in potatoes is planned.

Resistance studies in the potato to common scab (*Actinomyces scabies*), Rhizoctonia scab (*Rhizoctonia solani*), Fusarium wilt, early blight, and late blight are in progress. The aim is eventually to combine resistance to these diseases with virus resistance in hybrids of good agronomic type.

Ten potato varieties and hybrids reputedly resistant to *Actinomyces* scab were tested in replicated field experiments against Late Carman and Factor controls. All the former were much less affected than the controls, and one, an unnamed Canadian hybrid, appeared specially resistant. No resistant variety was equal to either control in yield.

Fifty-four potato varieties were subjected to a preliminary test for resistance to *Rhizoctonia solani*. Part of each variety was harvested at each of three stages of growth; separate ratings were made for susceptibility to cortical lesions of stolons and stem-bases, and to the formation of sclerotia on the mature tubers. Differences in susceptibility were much less marked than for *Actinomyces* scab; about ten varieties less affected than the average were selected for further testing against a few of the most severely affected.

The potato work has reached the stage where it is becoming of direct use to State Departments of Agriculture. Agronomic investigation and development of the more promising resistant hybrids is being undertaken by potato specialists of the Victorian, Tasmanian, and Western Australian Departments of Agriculture.

(ii) *Tomatoes.*—Agronomic studies of tomato varieties under different environments, a project occasioned by the war, has been completed, and is to be written up and published in the Council's *Journal.* Work on Fusarium resistance has been continued, and a preliminary study of this aspect in tomato varieties and species has been completed and reported in the Council's *Journal* for November, 1946, p. 376. Further work has shown that the high resistance of Pan America to Fusarium wilt is readily inherited in crosses with commercial varieties. Hybrids of high yielding ability and possessing the high resistance of Pan America have been developed and they are being tested in various parts of Australia. Some have shown distinct promise under conditions in the Mildura district of Victoria where local varieties have failed owing to the depredations of Fusarium wilt.

Tomato hybrids showing promise are being developed by agronomic selection by the tomato specialists of Victoria, New South Wales and Queensland. A study of the factors affecting resistance to Fusarium wilt in Pan America and resistant hybrids developed from it is in progress. Early blight of the tomato is a major problem in a number of the important tomato areas in Australia. A project is in progress to develop resistance to this disease.

Work on resistance to the virus of spotted wilt in the tomato has been in progress for some time without producing positive results. The high resistance, amounting almost to immunity, of *Lycopersicon peruvianum* has been confirmed a number of times. The difficulties associated in its hybridization with commercial varieties have resulted in a search being made for resistance among *L. pimpinellifolium* strains. One strain has shown some promise, and work on hybrids between it and commercial varieties is in progress.

(iii) *Peas.*—Flowering in relation to pod setting and yield has been studied in a number of pea varieties. This project will be completed in the coming season.

Ascochyta resistance has been found in a few European peas which are of a primitive type. It has been shown that this resistance is heritable in crosses with commercial canning and garden types. A co-operative project is in progress with the Victorian Department of Agriculture to develop a pea of the Greenfeast type possessing resistance to *Ascochyta pisi.*

Bacterial blight of peas causes sporadic and severe losses in Australia, and a search is being made for material resistant to it. A technique for sterilizing seed infected with bacterial blight has been developed; preliminary trials have shown it to be satisfactory. Powdery mildew and downy mildew are serious on occasions in pea crops. Pea varieties resistant, but not in all cases completely resistant, to these fungi have been found and hybridized with commercial varieties. Studies on cold and frost resistance in peas have been in progress for some time. The American variety Wando has been shown to have better than average cold resistance.

(iv) *Beans.*—Concentration of work has been mainly on Halo and common American blight resistance in beans. The relation between plant resistance and pod resistance in a number of varieties is being investigated with the aim of isolating varieties resistant to these diseases in all stages of their life histories.

Field observations on root and basal stalk rot of beans were continued, and trials of the resistance of many varieties and strains gave results similar to those obtained in previous seasons, indicating marked differences in susceptibility, both between varieties and sometimes between strains of a given variety.

Numerous isolates of several Fusaria and of *Macrophomina phaseoli* from diseased bean plants were tested for pathogenicity at high temperatures in pots and soil temperature tank cans of sterilized soil. There were no consistent differences between the aerial parts of control and inoculated plants. At the start of senescence, the root systems were washed out. Two Fusarium species caused significantly more rotting of the stem-bases of inoculated plants than occurred in the controls, but *Macrophomina* did not. The worst rotting occurred in pots inoculated with chopped diseased bean roots.

10. *Tomato Spotted Wilt.*—Field experiments were made at Sydney and Canberra to test the possibilities of applying the multiple planting method, as developed for the control of the disease on tobacco in South Africa, to tomato crops. At Sydney, normal single planting was compared with triple planting and with triple planting plus spraying with 0.1 per cent. DDT at two-week intervals. At Canberra the experiment was made in two stages: (*a*) as a multiple planting plot similar to Sydney with the exception that spraying with DDT was done at weekly intervals; (*b*) after thinning at the conclusion of stage (*a*), as a spray trial on normal spacing to compare DDT with Gammexane for thrips control.

At Sydney, the incidence of infection was extremely high (the controls were 100 per cent. infected after five weeks), and at Canberra extremely low, making the statistical examination of the data difficult. However, in some respects the results at both places were essentially similar. It was calculated that the effect of DDT spray on the triple-planted plots was to reduce infecting thrips attack to a quarter of that on the unsprayed plants. The calculated effect of triple planting was only partially attained, apparently because of the attractive effect for thrips of the greater mass of greenery in the multiple planted plots. The results of stage (*b*) of the Canberra plot indicated that significant control of spotted wilt was obtained by the use of DDT, infection being reduced by approximately 50 per cent. Slight control was obtained with Gammexane but the degree was not significantly better than unsprayed plots.

Observations were continued on field symptoms of spotted wilt on dahlias, and further study made of the problem of obtaining infection of dahlia by mechanical inoculation.

The study of the spotted wilt virus affecting potatoes was continued in greenhouse and field. Spotted wilt was epidemic again in 1946-47 in field crops of potatoes both in New South Wales and Victoria. Large numbers of tubers from diseased plants were tested, and it was confirmed that approximately 30 per cent. carried the virus and gave rise to secondary diseased plants. Preliminary observations indicated that delaying planting until December resulted in great reduction in incidence of spotted wilt. As noted in the last report, the virus affecting potatoes is a strain complex lacking tip blight, the most severe strain. Further work has shown that in the virus present in potatoes the ringspot strain is dominant and the symptoms are primarily those of this strain.

11. *Northern Australia Regional Survey.*—As mentioned in the previous report, a survey of Northern Australia is being carried out by the Council on behalf of the Northern Australia Development Committee. This survey is intended to determine the best way of using areas in the Northern Territory. In the first year, 1946-47, an examination was made of the Katherine-Darwin area; in 1947-48 attention is being turned to the Barkly Tableland.

The object of the survey is to record the nature of the country as accurately as possible, to assess its potentialities, and to make recommendations with respect to its development. A number of recommendations have been made to the Northern Australia Development Committee following the 1946 survey, and a full report of that survey is to be published.

12. *Other Investigations.—Fertilizer Experiments in Pine Plantations.*—Plots of *Pinus taeda* at Woodburn pine plantation, treated once with ¾ cwt. of superphosphate per acre in 1941, or with 1½ cwt. per acre in 1939, gave an initial response in faster growth rate, improved appearance, and lessening or disappearance of "needle fusion" symptoms, but the effect of these treatments now appears to have largely worn off. Plots treated with 3 cwt. per acre in 1939 are also showing signs that the fertilizer treatments need renewal to maintain healthy growth. "Needle fusion" symptoms are re-appearing and the extra growth of the fertilizer as compared with the control plots is less marked, though these changes are less evident in the 3 cwt. than in the ¾ and 1½ cwt. plots. The 3 cwt. treatment has already produced enough extra timber to show a substantial profit over the compounded cost of application, as also have treatments of 2½ cwt. per acre of ground rock phosphate or 2 cwt. of superphosphate, applied to adjacent plots of *P. caribea* in 1939. The difference between the growth rates of the latter plots and the controls is also becoming less marked, though there has not yet been any re-appearance of "needle fusion" in the treated plots of *P. caribea.*

13. *Publications.*—The following papers were published during the year:—

Anderson, A. J. (1946).—Fertilizers in pasture development on peat soils in the lower south-east of South Australia. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 394-405.

——(1946).—Molybdenum in relation to pasture improvement in South Australia. Ibid. 19: 1-15.

——(1946).—Plant responses to molybdenum as a fertilizer. 1. Molybdenum and symbiotic nitrogen fixation. 2. Factors affecting the response of plants to molybdenum. Coun. Sci. Ind. Res. (Aust.), Bull. 198.

Bald, J. G. (1946).—A plan of growth, maturity, and yield of the potato plant. *Emp. J. Exp. Agric.* 14: 43-8.

Cashmore, A. B., *et al.* (1946).—Control of cape-weed (*Cryptostemma calendulaceum* (L.) R.Br.) in flax. *J. Coun. Sci. Ind. Res.* (Aust.), 19: 1-4.

Cashmore, A. B., and Campbell, T. G. (1946).—Weeds problem in Australia: a review. Ibid. 19: 16-31.

Davies, J. G., and Greenham, C. G. (1946).—Eradication of *Hydrocotyle tripartita* R.Br. from golf and bowling greens. Ibid. 19: 335-40.

Dickson, B. T., and Hartley, W. (1946).—Rubber-growing in Australia. *Trans. Inst. Rubber Ind.* 22: 17-24.

Dickson, B. T. (1946).—Some thoughts about agriculture. *J. Aust. Inst. Agric. Sci.* 12: 1-4.

Donald, C. M. (1946).—Competition between pasture species with reference to the hypothesis of harmful root interactions. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 32-7.

Greenham, C. G. (1946).—Application of interferometry to biological surfaces. *Aust. J. Sci.* 9: 26.

Hutton, E. M. (1946).—Relationship between necrosis and resistance to virus Y in the potato. 3. Interrelation with virus C. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 273-82.

Loftus Hills, K. (1946).—Suitability of a number of varieties of opium poppy for the production of morphine from the ripe capsule. Ibid. 19: 177-86.

Loftus Hills, K., and Kelenyi, G. P. (1946).—A preliminary report upon the cultivation of *Duboisia* spp. Ibid. 19: 359-75.

Loftus Hills, K., and Rodwell, Cynthia (1946).—Distribution and nature of the alkaloids in developing seedlings of *Duboisia myoporoides* and *Duboisia Leichhardtii.* Ibid. 19: 295-302.

Loftus Hills, K., Trautner, E. M., and Rodwell, Cynthia (1946).—A tobacco-*Duboisia* graft. *Aust. J. Sci.* 9: 24-5.

Mills, Margaret, and Hutton, E. M. (1946).—Fusarium wilt of tomato in Australia. 1. The relationship between different isolates of the pathogen and resistance in varieties of *Lycopersicon esculentum* Mill. and other *Lycopersicon* species. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 376-87.

Moore, C. W. E. (1946).—Effect of soil moisture content and depth of planting on the germination of dehulled seed of *Danthonia semiannularis.* Ibid. 19: 172-6.

Norris, D. O. (1946).—Failure with "DDT" and success with "Gammexane" in the control of the culture mite. *J. Aust. Inst. Agric. Sci.* 12: 51-2.

——(1946).—Recent advances in plant protection fungicides. *Aust. J. Sci.* 9: 1-6.

Wark, D. C. (1946).—Some observations on the magnitude of agronomic variation within cabbage varieties and a description of varieties. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 347-58.

III. ENTOMOLOGICAL INVESTIGATIONS.

1. *General.*—The most important development during the year has been the change in the cattle-tick situation resulting from the investigations, of an immediately practical nature, carried out by the Division of Economic Entomology's team of workers in Queensland. Whereas at the beginning of 1946 cattle-owners in that State were extremely worried by the problem presented by the increasing arsenic-resistance of ticks, and in June of that year it was only possible to report promising results obtained in preliminary experiments with a water-miscible preparation of DDT, during the last twelve months the practicability of using this material in dipping vats, and its efficacy, have been thoroughly established, and the anxiety of cattle-owners has given place to confidence.

Much of the work being carried out by the Division on the chemical control of insect pests has been concerned with the use of DDT and Gammexane (hexachlorcyclohexane, referred to in the last annual report as "666"), though attention has been given to some more recently developed insecticides. In the investigation resumed in Western Australia, after an interruption over the war years, very interesting and promising results have been obtained with DDT and Gammexane dusts against the red-legged earth mite. In general, work with these insecticides is now not so much a matter of establishing their efficacy against different pests, as a determination of the best methods of applying them, together with a definition of their limitations.

The Division's biological control investigations, which form a major part of its activities, have shown very satisfactory progress. The introduced insect enemies of St. John's wort are continuing to clear land of the weed at an undiminished rate; and very large numbers of the beetles have been collected and distributed. The introduction and breeding of parasites of the cabbage moth comprised one of the new projects initiated during the year.

Other new investigations started include a biological study of the Dawson River sandfly, which appears as a serious pest of stock in parts of Queensland after heavy rains; laboratory studies of what may be termed the competition factors controlling the levels of insect populations; and ecological studies of cockchafer beetles, the larvae of which (popularly known as "curl grubs" or "white grubs") are a serious pest of pastures. This last-mentioned investigation is being carried out in collaboration with other interested bodies (see later).

After a lapse of eleven years without a meeting—during which interval DDT and Gammexane had been developed and tested on a large scale against this important orchard pest—a meeting of the Codling Moth Committee was convened at Canberra in May, 1947. The Departments of Agriculture of all six States, the Waite Agricultural Research Institute, and the Division of Economic Entomology were represented at the meeting. The results of the past two seasons' trials, which had demonstrated the efficacy of DDT for controlling codling moth, were discussed, and lines of work which the Division might profitably take up were suggested. Advantage was taken of the presence of the State Entomologists in Canberra to discuss other problems of common interest.

2. *Cattle Tick.*—The main object of the work undertaken during the year was to give graziers some relief from the disabilities they were suffering as a result of the increasing prevalence of arsenic-resistance in ticks.

(i) *Control of Ticks on Grazing Properties.*—DDT, as a 0.5 per cent. suspension in the form of Rucide, has been studied in sixteen dipping experiments on ten widely separated properties in Queensland. It has proved superior to arsenic in every respect except cost and ease of preparation, its chief advantages being: absence of irritation, so that cattle thrive better; effectiveness against arsenic-resistant ticks; and residual toxicity for one to three weeks after dipping, as a result of which the tick population is greatly reduced and the intervals between dippings consequently prolonged. It is also active against other pests, which are unaffected by arsenic. Suspensions have been shown to remain active in dipping vats for more than a year.

(ii) *Cleansing Experiments.*—These were designed to show whether DDT could be used to cleanse cattle completely of ticks for movement from infested into clean country. Thirteen sets of observations were made, and the conclusion has been drawn that dipping twice in suspensions containing not less than 0.35 per cent. DDT, with an interval of three to six days between dippings, will cleanse cattle efficiently, provided the animals are in fat or good store condition and are not grossly over-infested with ticks. In the case of impoverished, very heavily infested stock, preliminary control of the ticks would be necessary before this cleansing procedure could be relied on.

(iii) *Chemical Investigations.*—No method of cleansing would be acceptable to State authorities unless the actual concentration of active ingredient in the dipping vat could be determined, so considerable attention was devoted to developing a routine method of DDT analysis, which could be used on dip samples. The procedure evolved has proved to be free from serious error in the analysis of some 500 samples of various ages and degrees of dirtiness; it is now in routine use. Special instructions for sampling dips containing DDT were also formulated.

As Rucide can be mixed only with soft or softened water, many determinations of water hardness have been necessary in the course of the work. A curve has been constructed showing the relation of total hardness to stability of the suspension, and an empirical rule developed to indicate the amounts of softener required.

(iv) *Toxicity of DDT.*—The experiment reported last year, in which cattle are being anointed weekly with oily solutions of DDT, has now run for fifteen months. The animals have remained well, and post-mortem examination of three killed at the end of twelve months showed no detectable microscopic or chemical evidence of poisoning. However, the treated group has not gained weight as rapidly as the controls; whether this is significant or not has yet to be determined.

(v) *Other Preparations.*—DDT, in the form used, has certain disadvantages, in that it is somewhat tedious to mix into a dipping vat, is unstable in hard waters, and even in soft waters a certain proportion appears to be lost, suspensions made to a calculated 0.5 per cent. DDT usually stabilizing at an actual 0.35 to 0.4 per cent. as determined by analysis. Studies of alternative preparations have, therefore, been initiated. One dipping experiment with Gammexane has been undertaken in association with Mr. P. A. Elliott of Moolboolaman. The kill of ticks was very good, but more information is required on persistence and

intervals between dippings before the relative merits of Gammexane and DDT can be assessed. Rather encouraging preliminary observations have also been made on a dispersible DDT powder and paste.

3. *Buffalo Fly.*—Active research on the control of this pest has now virtually ceased, it having been shown that the "partial spraying" technique described last year for dairy cattle is equally effective for beef cattle which are handled at regular intervals, e.g., for dipping in arsenic. In this way, efficient control may be maintained at an annual cost of less than 3d. per head. Moreover, it has been found that dipping in DDT to control cattle tick apparently results in complete local extermination of the flies. Experience in North Queensland has, however, also demonstrated that these measures are effective only when they can be applied regularly and efficiently, so that the buffalo fly problem of the "outback" properties still remains to be solved.

4. *Sheep Blowfly.*—In collaboration with the Animal Health Station of the Queensland Department of Agriculture and Stock, experiments were carried out to test the efficacy of light spraying with DDT on the tip of the fleece, which had previously given encouraging results in preventing experimental body strikes in the insectary at Canberra. In addition to a semi-field experiment at Yeerongpilly, three sets of field experiments in the Stanthorpe district and two in the Clermont-Emerald area were undertaken during the year. Results indicate that some degree of protection is given, but it appears to be insufficient for practical purposes. The work is to be continued, with special reference to the rate and mechanism of loss of DDT from the fleece and to the use of heavier dosages.

5. *Dawson River Sandfly.*—Preliminary work has been commenced on this blood-sucking insect, which occasionally has a serious effect on stock, and is a possible vector of worm-nodule in cattle. Of the eight species of Simuliidae now known from Queensland, only one (an undescribed species of *Austrosimulium*) is a pest. It breeds in enormous numbers in very fast, muddy water near the middle of flooding streams, its larvae and pupae attaching especially to partly submerged tea-trees (*Melaleuca*). The breeding period is short, and is probably restricted to one generation, unless further "freshes" come down the stream. The adults congregate in tea-trees, and appear to attack man, cattle, and sheep with equal readiness, though kangaroos were probably their original source of food. The resistant stages, which enable the species to persist between floods, have yet to be discovered.

6. *Insect Physiology and Toxicology.*—(i) *General.*—Research activity in this field has been somewhat reduced during the past year owing to the absence abroad of two members of the physiology and toxicology team. A good deal of work has been carried out in collaboration with other investigators, e.g. on the cattle-tick problem (methods of analysis of DDT dips) and on vegetable pests (breakdown of DDT in dust mixtures), and is referred to elsewhere.

(ii) *Housefly.*—Further work has been carried out on the mode of action of adjuvants ("activators") of pyrethrum, special attention being given to lubricating oil. It has been shown that the adjuvant effect of lubricating oil in fly sprays is due to its relatively low volatility, which tends to decrease the rate at which spray droplets diminish in size as the carrier-solvent evaporates.

The effects of starvation for varying periods on the susceptibility of houseflies to pyrethrum, and their behaviour during exposure to pyrethrum sprays, have been investigated. The results obtained suggest a way of increasing the efficiency of the Peet-Grady method of testing fly sprays.

A constant-pressure air valve for the standard atomizer used in the Peet-Grady method has been developed, and a description of it published. This attachment does not affect the atomizing characteristics of the spray-gun, but ensures that all the spray fluid is dispensed at the right constant pressure.

(iii) *Insect Muscle Respiration.*—As part of a programme of research into the enzyme systems concerned with respiration and energy exchange in insect tissues, an investigation on the enzyme adenosinetriphosphatase of insect muscle is being undertaken. It has been found that the adenosinetriphosphatase of insect muscle, unlike that of vertebrate muscle, is not firmly attached to the contractile protein, myosin, but can be obtained in aqueous solution. Studies on the substrate specificity, pH optimum, and the effect on activity of inhibitors and various metal ions have revealed other important differences between the enzyme of insects and that of higher animals. Some progress has been made in purifying the insect adenosinetriphosphatase.

7. *Biological Control.*—During the past year, although the possibilities of extending biological control activities to cover additional pests were explored, active work was confined almost exclusively to three major projects: insect control of the noxious weed St. John's wort (*Hypericum perforatum*), and control by hymenopterous parasites of the potato moth (*Gnorimoschema operculella*) and the cabbage moth (*Plutella maculipennis*).

(i) *St. John's Wort.*—Inspections made in St. John's wort areas in Victoria and New South Wales during November and December, 1946, showed that, for the most part, colonies of the introduced insects were making very satisfactory progress. In the Oven's Valley (Victoria), where the increase of the insects and the control of the weed have reached a more advanced stage than elsewhere, the two Chrysomelid beetles, *Chrysomela hyperici and C. gemellata,* as a result of natural as well as artificial spread, occur together throughout a considerable extent of infested land, and it is only possible to collect reasonably pure lines of either species in certain restricted areas.

(*a*) *Chrysomela hyperici.*—In Victoria, this species is continuing to increase at a number of points in the vicinity of Bright, and at Oven's Vale, near Myrtleford, a considerable area of the weed in pine plantations has been heavily attacked and much of it destroyed. In New South Wales, colonies in the Piambong and Rylstone districts continue to make satisfactory progress, and in the Mannus Valley, near Tumbarumba, the colony started in 1944 has extended considerably, and part of the reclaimed area is re-occupied by a thick sward of grass. From South Australia and Tasmania, where liberations of *C. hyperici* have also been made, no recent reports have come to hand, but it would appear that the insects are now well established at certain points and making satisfactory progress.

(*b*) *Chrysomela gemellata.*—In the 1945-46 Report, the opinion was expressed that this species was the most effective of the three *Hypericum* insects now established in Australia; the spectacular progress that it has made during the last twelve months confirms this opinion. In the Bright district, *C. gemellata* is now established in very large numbers, and appreciable areas of good agricultural and pastoral land are being reclaimed at an increasingly rapid rate; little or no regeneration of the weed has taken place. Most of the redistributions made during the last two years have consisted of this species. During the past season, distributions of *C. gemellata* to areas in Australia and overseas reached a total of approximately 1,046,000. Of these, rather more than half were distributed in various parts of Victoria (mainly in the Ovens and Kiewa Valleys, some in the Benella and Rutherglen districts) by officers of the

Vermin and Noxious Weeds Branch of the Department of Lands and Survey. In New South Wales, liberations totalling 200,000 were made in association with the Weeds Officer, Department of Agriculture, at Mannus, near Tumbarumba; in the Mudgee district (Piambong, and on the Catchment Area); and at Nullo Mountain, near Rylstone. A further 200,000 collected by officers of the Division of Economic Entomology were forwarded to South Australia, for liberation in the Port Lincoln area by the Waite Agricultural Research Institute.

(*c*) *Agrilus hyperici.*—The area at Baker's Gulley, Bright, where one of the main colonies of this root-boring beetle is established, has now been largely occupied by *Chrysomela gemellata.* Although at present the effect of the inter-specific competition cannot be accurately assessed, general observations indicate that incidence of *Agrilus* has been reduced. At Piambong and the Mudgee Catchment Area, the position relating to the establishment of *Agrilus* appears to be much more satisfactory. Samples taken at both sites showed that over 50 per cent. of the plants within the areas occupied by the colonies were being attacked, a number by more than one larva. The weed in both places showed some reduction in the vigour of the plants, as well as an appreciable degree of reduction in density.

(*d*) *Overseas shipments.*—It was possible during the 1946-47 season to send further consignments of *Hypericum* insects to America, to assist the "Klamath Weed" control project being carried out in California by the United States Department of Agriculture in co-operation with the University of California. These two consignments included 43,000 *Chrysomela gemellata* and 58,000 *C. hyperici.* Very satisfactory progress in the project has been reported from California during the past year, and if additional large numbers of *Hypericum* insects can be shipped from Australia during the coming season, further introductions will probably not be necessary.

(ii) *Potato Moth.*—Improvements in equipment and technique made it possible to breed certain of the imported potato moth parasites in large numbers, and rendered unnecessary further introductions from overseas. The large-scale breeding and distribution of the polyembryonic Encertid *Copidosoma koehleri* formed the main part of the season's programme of work, although the breeding of the Braconids, *Chelonus phthorimaeae* and *Microbracon gelechiae,* was continued and further distributions of these parasites were made. As in the 1945-46 season, liberations were made almost exclusively in areas where large-scale potato-growing forms a permanent feature of the local agriculture. In pursuance of this policy, liberations of *Chelonus* (each of 1,000) insects were made at Crookwell and West Maitland, and 1,500 *Microbracon* were released in the former area.

A total of 610,000 *Copidosoma* were liberated during the 1946-47 season, 200,000 at Crookwell, 110,000 in the West Maitland district, New South Wales; and in Queensland, 200,000 in the Lowood district and 100,000 at Stanthorpe. The lastmentioned liberation was made against *Gnorimoschema operculella* reported to be causing serious losses to tomato crops. The Queensland liberations were carried out by officers of the Department of Agriculture and Stock.

Following the large liberations of *Copidosoma koehleri* that have been made in the Crookwell area during the last two years, some observations have been made on field recoveries of the parasite. These have indicated that up to 10 per cent. of the potato moth larvae in a given plot in which *Copidosoma* had been released may be parasitized in subsequent generations. In this district the parasite is able to survive the winter in the pupal stage in field cages, but it is not yet known whether this is the normal overwintering stage, nor whether *Copidosoma* can overwinter successfully under ordinary field conditions.

(iii) *Cabbage Moth.—Angitia cerophaga* Grav., an Ichneumonid parasite of the larval stage of the cabbage moth, was introduced into Australia some years ago but was not established. It was again imported in December, 1946, from New Zealand, through the co-operation of the Cawthorn Institute, Nelson, and it has been liberated in the Australian Capital Territory. The parasite can now be recovered with ease in one locality, and is thought to be established. The techniques used elsewhere for the breeding of this insect were found to be unsatisfactory, and a new method is being developed. *Angitia* should be available for general liberation by next spring.

Another Ichneumonid parasite, *Diadromus collaris* Grav., which attacks the pupal stage, has been obtained from Tasmania, the specimens received being part of a consignment from New Zealand. A flourishing colony now exists in the laboratories at Canberra, and it is expected that this parasite will also be available for general distribution before long.

8. *Population Dynamics.*—The control of an insect pest generally consists of reducing the population density of the species from a level that is economically too high to a lower one that is tolerable. To bring about this control intelligently, it is necessary to understand the mechanism that regulates population densities, but unfortunately little is known at present about this mechanism. Basic studies of population dynamics in their simpler forms have therefore been resumed, using various species of blowflies and the housefly in the experiments. As new ground is being broken, most attention during the year has been given to developing suitable new techniques and apparatus, but important preliminary results have been obtained. These provide the necessary basis for future critical experiments. The preliminary results have indicated that competition for food can produce results of a complexity that was previously unsuspected.

9. *Australian Plague Locust (Chortoicetes terminifera).*—During the spring of 1946, numerous hopper swarms of *Chortoicetes* developed in the Trangie district from eggs laid by swarms of the previous autumn. The opportunity was taken to carry out detailed observations on the behaviour of these swarms. These observations, which covered the development of gregarious behaviour, band formation and marching, the effect of different pasture types on the form of hopper bands and the direction of movement, feeding, &c., have been completed and prepared for publication.

Observations on the times of feeding of hopper bands showed that these vary widely according to temperature and other factors. Thus for best results from poison baiting as a control measure, the operator needs to have considerable knowledge of the habits of the insect, and should make his applications of bait so as to coincide with a readiness on the part of the hoppers to feed. This requirement militates against successful locust control by poison bait, and emphasises the desirability of further tests in the use of contact insecticides, such as Gammexane or "DNOC", which are not subject to this limitation.

Work on ecological control of *Chortoicetes* has been continued from the Trangie Field Station. Old-man saltbush, *Atriplex nummularia,* still gives great promise as a constituent of barriers for planting between the oviposition and food-shelter habitats of outbreak centres. The problem of finding a satisfactory tree for such barriers still remains unsolved.

The scalded areas that were fenced and sown with various colonizing species in furrows have continued to show very little re-vegetation, and this approach to

the rehabilitation of scalds must be dismissed as a failure. On the other hand, the experiment in which branches were laid on four areas of scald, with the object of catching wind-blown sand in which seed might germinate, is showing considerable promise. The branches have not only accumulated a certain amount of sand, but they also catch and hold both seeds and seed-heads, and considerably impede the flow of water off the scald after rain, so that the soil under them remains saturated for some time after it has dried out elsewhere on the scald. Following 5 inches of rain in February, many plants, including a high percentage of perennial grasses, germinated under the branches, but none at all on the control areas. The progress of the young plants is being recorded photographically at suitable intervals.

The experiment with the branches was suggested by the observation that plants tended to germinate in accumulated sand along the fence surrounding the scald plot. Once some growth has occurred there, the plants hold water flowing off the scald, so that a broad band of new pasture is spreading over the scald from the fence on its downslope side. This advance is being recorded.

In view of the satisfactory performance of old-man saltbush on all kinds of soil, a new section of scald has been fenced and is being planted with saltbush seedlings. It is hoped that a sufficient number will become established to form their own wind and water barrier and thus allow of the germination of pasture plants beneath them, producing eventually a salt-bush-grass pasture.

A new piece of work has been undertaken to obtain quantitative information an the effect of the presence of trees on locust numbers. Further observations are required along these lines, but it is already apparent that the planting of trees at not excessive densities would render an outbreak centre much less effective in producing swarms. A test has been made of the value of aircraft as a means of locating outbreak centres and hopper swarms. Even using a slow-flying Avro-Anson at 100-200 feet, the results were disappointing, and it was concluded that a helicopter would be required for successful aerial survey work of this kind.

Further progress has been made in the analysis of past outbreaks of *Chortoicetes* and in studies of the taxonomy and phases of species of *Chortoicetes* and *Austroicetes,* the parasitic mites of Acrididae, and the biology of the predacious wolf-spiders.

10. *Pasture Cockchafers.*—In July, 1946, it became possible for the first time to allot a scientific officer to carry out full-time investigations on the important problem of cockchafer grubs in pastures. A number of species of the family Scarabaeidae are known to damage pastures in the larval stage, but the most important of these is a species of *Aphodius,* usually identified as *A. howitti* Hope. This pest has been causing concern to graziers in Victoria, South Australia, and Tasmania for a number of years. It is particularly numerous in sown pastures of high carrying-capacity. The grub is the larval stage of a small dark brown beetle which has a brief swarming flight in about February of each year. So far as is known, the adult beetle is quite harmless—all the damage being inflicted by the larva, which lives in a vertical burrow in the soil during the day, and comes up at night to feed upon the pasture, a part of which it drags down the burrow for future consumption. When grubs are numerous, their earthen castings may lie so thickly upon the surface of the denuded pasture as to give the appearance of a fallow.

Although *Aphodius* can be controlled quite simply when it occurs in lawns and golf-courses, the methods available are too expensive for use on grazing paddocks. Since practically nothing is known of the ecology of the insect, it is quite evident that intensive fundamental investigations are needed before suitable methods for its large-scale control can be devised. To avoid overlapping between the Division's investigations and those projected by the Waite Institute and the Victorian Department of Agriculture, a Pasture Cockchafers Committee representative of these organizations was set up towards the end of 1946. Subsequently, the Tasmanian Department of Agriculture also nominated a representative. The Committee has drawn up a general programme of research on *Aphodius* and other pasture cockchafers, and has allotted special responsibility for different aspects of the problem to each constituent organization. An information service, from which it is hoped to ascertain the extent of the infestation in different seasons is being organized.

The Division's investigations have been carried out mainly in Canberra, where a heavy infestation of *Aphodius* was discovered on the Dickson Experimental Farm. Although still of a preliminary nature, they have yielded much valuable new information on the life-cycle, behaviour, and ecology of *A. howitti* and other species.

The cockchafers as a group are inadequately known in the adult stage, and in relatively few species have the larval stages been described and correlated with the adults. Accordingly arrangements have been made for a specialist in the British Natural History Museum to undertake a general taxonomic revision of the Melolonthinae, the subfamily that includes many of the pest species, and for a New Zealand entomologist at present in Australia to revise the Aphodiinae, to which *Aphodius howitti* belongs. The immature stages of *A. howitti* are being studied at Canberra.

11. *Red-legged Earth Mite* (*Halotydeus destructor*).—Investigations into this important pasture pest, which were discontinued during the war, have been resumed in Western Australia. During the summer months, laboratory studies have been carried out at the Institute of Agriculture, Perth; and during the season of mite activity (approximately April-November), field experiments have been conducted in the Katanning district, where damage caused by the pest is at times very severe.

In the field experiments, the efficacy of DDT and Gammexane was studied. In preliminary trials, heavily infested subterranean clover pastures were treated with 2 per cent. DDT and Gammexane in superphosphate at the rate of 2 cwt. per acre. (Crude Gammexane, containing approximately 12 per cent. of the active gamma isomer was used.) An excellent kill (over 95 per cent.) of mites was obtained in both treatments. Further trials, designed to determine the dosages necessary to produce a kill approaching 100 per cent., and the persistency of the treatments, were accordingly carried out in the 1947 season.

In these experiments, 2 per cent. and 0.5 per cent. DDT and Gammexane dusts were used, and each applied at the rate of 2 cwt. and 1 cwt. per acre. Over 95 per cent. kill of mites was obtained with the lower dosage of the 0.5 per cent. DDT and Gammexane dusts. When applied at the rate of 2 cwt. of 2 per cent. dust per acre, DDT revealed outstanding persistency, remaining potent on the soil for at least two and a half months, whereas the comparable Gammexane treatment appeared to lose its potency in from one to two months.

These results indicate that the earth mite could be effectively controlled by DDT or Gammexane dusts. The cost of applying the dosages used in these experiments would, however, be excessive. The persistence of low dosages of DDT is now being studied, as a preliminary to investigating the possibility of attaining effective and economic control by a single application, combined with the normal annual top dressing

with superphosphate, which is usually carried out in March, i.e. between one and two months before the first appearance of the mites.

In the course of the work, some interesting observations were made on the effect of DDT and Gammexane dusts on other species. The lucerne flea (*Sminthurus viridis*) appeared to remain unharmed by contact with DDT, in the dosages used in the experiments, but succumbed comparatively rapidly to the Gammexane dust. On the other hand, the Bdellid mite, *Biscirus lapidarius,* which is a predator on the lucerne flea, appeared to be killed by the DDT dust but unaffected by the Gammexane. Controlled experiments are being carried out to confirm these observations.

Marked differences in the susceptibility to earth mite attack of various species of legumes (*Vicia* spp., *Lathyrus* spp., and *Trifolium* spp.) have been noted, and a selected series of these has been planted to provide material for an investigation into the basis of this variation. In the first place, it is intended to compare the micro-anatomy of the leaf structure.

12. *Insect Vectors of Plant Viruses.*—(i) *Tobacco Yellow Dwarf.*—The investigation of yellow dwarf virus disease of tobacco was continued, in co-operation with the Division of Plant Industry, at Canberra during 1946-47. Records of the prevalence of the vector, *Orosius argentata* (Evans), showed that this insect first appeared on 27th August, 1946, and continued to be caught in the mechanical nets until the end of December. The jassid was most abundant in September.

An experiment designed to determine whether the incidence of the disease could be reduced, to a degree that would be significant in commercial practice, by multiple planting and roguing, by the use of DDT sprays, or by a combination of the two methods, had to be abandoned in January owing to the low incidence of the disease and an infection of blue mould.

(ii) *Potato Virus Disease.*—The survey, begun in 1941, of the abundance of the green peach aphis (*Myzus persicae*) and the potato aphis (*Macrosiphum solanifolii*), vectors of leaf roll and mosaic diseases of potato, was continued. The spring population at Canberra was low, and appeared earlier than usual; there were no massed flights of winged forms, and aphids continued to be caught in the mechanical nets until the end of December, seven weeks later than in other seasons. A small autumn generation appeared in March and April.

13. *Orchard Pests.*—Investigations into the control of the oriental peach moth (*Cydia molesta* Busck.), the codling moth (*Cydia pomonella* L.), and the red spider and mite (*Tetranychus urticae* and *Bryobia praetiosa*) were continued. Good results were again obtained with a 0.1 per cent. DDT emulsion spray. Under the conditions of the experiments carried out at Narrabundah, Australian Capital Territory, however, DDT emulsions of 0.06 per cent. or lower concentration proved inferior to treatment with 0.5 per cent. lead arsenate plus 1 per cent. white oil for the control of codling moth.

Special attention was given to two acaricides, which were tested against the red spider and red mite infestations that developed following DDT treatment. Dicyclohexylamine dinitrocyclohexylphenate, incorporated in two DDT cover sprays against codling moth, controlled the mite but not the spider. Hexethyl tetraphosphate ("H.E.T.P.") gave a complete kill of red mite and red spider present at the time of application, but did not prevent reinfestation by the spider.

14. *Field Crop and Vegetable Pests.* — (i) *Potato Moth (Gnorimoschema operculella).*—In field experiments at Canberra, two sprays containing, respectively, 0.1 per cent. DDT and 0.4 per cent. "Ryanex" (prepared from the ground wood of *Ryania speciosa*), and a 5 per cent. DDT aerosol (giving a dosage of DDT comparable with that obtained with the 0.1 per cent. spray) were tested for protection of the haulms from potato moth attack during the growing period. Two applications were made in each case. The DDT spray proved the most effective, followed by the aerosol. The Ryanex treatment was not significantly better than the untreated control.

In large-scale trials at Crookwell (New South Wales) three fields of potatoes were dusted twice with 2 per cent. DDT at three-weekly intervals. The efficacy of the treatment is indicated by the figures for percentage infestation of tubers recorded at harvest, being 7.2, 8.5, and 15.9 for the treated plots, compared with 29.5, 17.1, and 38.5 for the untreated control plots.

Final adaptations of power spraying and dusting machinery for the field-scale application of insecticides to crops were made during the year.

(ii) *Cabbage Moth and Cabbage Butterfly.*—Nine field trials, involving a total of 19,000 cabbages and 9,000 cauliflowers, were carried out during the 1946-1947 season. Of the new insecticides tested, hexethyl tetraphosphate ("H.E.T.P."), the German preparation "Nirosan Spritzmittel", and the American "Ryanex", failed to give effective control of moth and butterfly larvae at the recommended dosages and strengths; but 3.5 per cent. "Gix" (a German preparation, the active principle of which is the fluorine analogue of DDT) proved effective.

The 1946-1947 results with DDT dusts and sprays confirmed those of the previous season, i.e. a 0.1 per cent. spray, a 0.05 per cent. spray, a 1 per cent. dust, and a 0.5 per cent. dust all gave effective control, ranging from excellent in the first named to satisfactory in the case of the last. The addition of rotenone and pyrethrum to the 1 per cent. DDT dust did not increase the larvicidal properties. The previous season's results with Gammexane were, however, not confirmed. Dusts containing 1 per cent. and 2 per cent. of the crude material (i.e. 0.12 per cent. and 0.24 per cent. respectively of the gamma isomer) proved significantly inferior to the 1 per cent. DDT dust; and under conditions of intense grub infestation, dusts containing as much as 2 per cent. of the gamma isomer proved less satisfactory than a 0.5 per cent. DDT dust.

(iii) *Cabbage Aphis.*—With the shortage of nicotine sulphate likely to continue for some time, special attention was paid to aphicides that may be more readily obtained. The plots used in the field trials mentioned above were sufficiently heavily infested with cabbage aphis (*Brevicoryne brassicae*) to provide satisfactory conditions for comparative tests.

The various aphicides were tested incorporated with DDT dusts and sprays, with the object of obtaining simultaneous control of moth, butterfly, and aphis. The following proved effective:—1 per cent. DDT dusts with added nicotine sulphate (5 per cent. v/w), "H.E.T.P." (5 per cent. v/w) and Gammexane (1 per cent. crude, 0.12 per cent. gamma isomer); and 0.1 per cent. DDT sprays with nicotine sulphate (0.125 per cent.), "H.E.T.P." (0.1 per cent.), Gammexane (0.1 per cent. crude), and soft soap (1 per cent.). In view of growers' preference for dust treatment, the shortage of nicotine, and the necessity of using hexethyl tetraphosphate preparations freshly made up (this was found to apply to dusts as well as sprays), it would seem that the DDT-Gammexane dust would be the treatment of choice for practical use.

Rotenone (0.5 per cent. and 1 per cent.) and pyrethrins (0.15 per cent. and 0.3 per cent.), when incorporated in a DDT dust failed to give adequate control of the aphis.

When the work with DDT and Gammexane was started, it was considered that these insecticides would affect the population of the cabbage aphis parasite

(*Diaretus rapae* Curtis), which occurs in large numbers in the Canberra district. However, although some mortality of adult parasites was observed after the application of DDT-nicotine and DDT-H.E.T.P. dusts, at the end of the season a high percentage of parasitized aphids was found on the experimental plots, when an infestation was present.

(iv) *Diluents for DDT Dusts.*—At an early stage in the experiments on the control of cabbage pests, the failure of certain DDT dusts (notably DDT-nicotine sulphate in hydrated lime) became apparent, and it was suspected that decomposition of the DDT occurred. Parallel studies in the field and the laboratory were therefore initiated.

In the field the following diluents for DDT-nicotine sulphate dusts were tested: Australian pyrophyllite, calcium hydroxide, calcium carbonate, magnesium carbonate, magnesium oxide, and barium hydroxide. The observation of the previous season was confirmed, i.e. calcium hydroxide as a diluent, in the presence of nicotine, caused DDT to fail as a larvicide. The results also indicated that barium hydroxide was significantly inferior to pyrophyllite, calcium carbonate, and magnesium carbonate, and that magnesium oxide was inferior to all diluents except calcium hydroxide.

The laboratory studies consisted of storage tests of DDT dusts made up with the above diluents, with and without nicotine. One experiment only has been completed, the results indicating that when the pure pp′ isomer of DDT is made up into a dust, with or without nicotine, a very rapid decomposition occurs with certain alkaline diluents. Some decomposition appears to take place in pyrophyllite, which might be serious in a storage period of several months, especially with nicotine.

15. *Termites.*—Research into various aspects of termite activity has been resumed and is now almost back to its pre-war basis. The most important development has been the resumption of laboratory testing. It is intended to employ this technique for the comparative evaluation of the natural resistance of about 20 species of Australian hardwoods known to have a certain degree of natural resistance which, it is considered, might be exploited to better advantage than has been done hitherto. To date, 10 series of tests, using *Eutermes exitiosus*, have been installed, primarily with a view to improving certain details of the technique and training new staff; but material of five timbers (*Eucalyptus pilularis, E. maculata, E. acineinioides, E. microcorys, and Tristania conferta*) has been received from Forestry Departments in New South Wales and Queensland, and routine testing will begin in July.

During the year, 122 series of termites from Eastern Australia, collected mainly by officers of the Division, have been identified. Data are being collected relating to the distribution, and intra- and inter-specific variation, of the species of the economically important genus *Coptotermes*. A study of the production of supplementary reproductives in *Porotermes adamsoni* and *Stolotermes victoriensis* has been initiated.

The annual routine examination of samples in the International Termite Exposure Test was carried out, and a report on their condition prepared for the American authorities.

Advice on various aspects of termite activity, but mainly concerning control and preventive measures, has been given to numerous enquirers, including several Government Departments, during the year.

16. *Miscellaneous Pests.*—(i) *Meat Ants* (*Iridomyrmex detectus Sm.*).—As a result of the successful experiments carried out in 1945-1946, using DDT and Gammexane dusts, a campaign of meat ant eradication in the city and suburbs of Canberra was initiated in October, 1946. The campaign was planned and carried out in co-operation with the staff of the Parks and Gardens Section of the Department of the Interior. In the course of the campaign, 3,241 colonies were treated.

The operators working in the southern half of Canberra used a 2 per cent. DDT dust at an average rate of one-third of an ounce per entrance hole; while those working in the northern half, and in Westridge, used a 5 per cent. crude Gammexane dust (0.6 per cent. gamma isomer) at the same dosage rate. The initial treatments were made in November and December, examinations and retreatments (where necessary) in February and April, 1947. The final examination in May showed that ants in most of the colonies had been killed out, and that the two dusts were equally effective.

Examination of colonies treated in the course of the 1945-1946 experiments, mentioned in the last report, showed that although the 5 per cent. crude Gammexane dust might not appear as effective as 2 per cent. DDT for the first three months or so after treatment, the long-range efficacy of the two was similar.

(ii) *Gladiolus Thrips* (*Taeniothrips simplex Mor.*).—Experiments of a preliminary nature were carried out on a commercial gladiolus farm at Fyshwyck, Australian Capital Territory. A 0.1 per cent. DDT emulsion effectively controlled the thrips and was significantly superior to a 0.2 per cent. crude Gammexane emulsion (0.024 per cent. gamma isomer) and to the usually recommended tartar emetic bait. Hexethyl tetraphosphate, applied as a 0.1 per cent. spray on the same schedule, failed to give control.

(iii) *Silverfish* (*Ctenolepisma longicaudata Esch.*).—An experiment in silverfish control, using a 10 per cent. DDT dust, and involving the co-operation of some 40 Canberra householders, was carried out during the year. Treatment consisted of blowing the dust into the crevices where the insects hide, e.g. behind skirtings, architraves, picture rails, cupboards, and on the upper surface of ceilings. Day-to-day records of dead silverfish picked up were kept. Used at the rate of 1½-2 lb. per house, the dust effectively controlled the pest, most houses being apparently entirely free from silverfish six months after treatment.

17. *Systematic and General.*—During the year many insects have been identified for entomologists and institutions in Australia and overseas. Additions have been made to the Division's reference collection of insects, including further specimens of mosquitoes from the Australian region, presented by Mr. D. J. Lee, of Sydney University.

Following the appointment, early in 1947, of a specialist in Diptera, a considerable amount of time has been devoted to sorting and re-arranging material of this group. The systematic revision of certain families of flies, and description of new species, have also been undertaken.

18. *Publications.*—The following papers were published during the year:—

Bald, J. G., Norris, D. O., and Helson, G. A. H. (1946).—Transmission of potato virus disease. 5. Aphid populations, resistance, and toleration of potato varieties to leaf roll. Coun. Sci. Ind. Res. (Aust.), Bull. 196.

Gay, F. J. (1946).—A case of house infestation by a tree-dwelling colony of *Coptotermes frenchi* Hill. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 330-4.

Gilmour, D. (1946).—The toxicity to houseflies of paints containing DDT. Ibid. 19: 225-32.

Greaves, T., and Rochford, R. R. (1946).—Observations on the relative susceptibility of potato varieties to attack by the Rutherglen bug (*Nysius vinitor* Berg.). Ibid. 19: 387-93.

Hackman, R. H. (1947).—The persistence of DDT on cattle. Ibid. 20: 56-65.

Helson, G. A. H. (1947).—A survey of insect pests and details of insecticide trials on army farms in the Northern Territory. Ibid. 20: 9-16.

——(1947).—Investigations on the control of oriental peach moth, *Cydia molesta* Busck., in the Goulburn Valley, Victoria. Ibid. 20: 17-26.

Hitchcock, L. F., and Mackerras, I. M. (1947).—The use of DDT in dips to control cattle tick. Ibid. 20: 43-55.

Kerr, R. W. (1946).—Control of fleas: laboratory experiments with DDT and certain other insecticides. Ibid. 19: 233-40.

Kerr, R. W., and Rafferty, W. J. (1946).—A constant-pressure air valve for the Peet-Grady atomizer. Ibid. 19: 241-4.

Norris, K. R. (1947).—The use of DDT for the control of the buffalo fly (*Siphona exigua* (de Meijere)). Ibid. 20: 25-42.

Waterhouse, D. F., and Fuller, Mary E. (1946).—The use of borax for the prevention of fly breeding in trap baits. Ibid. 19: 321-9.

Wilson, F. (1946).—The use of mineral dusts for the control of wheat pests. Coun. Sci. Ind. Res. (Aust.), Bull. 199.

(Note.—In addition to the publications listed above, the following Bulletins by officers of the Division, which would normally have been published during the year, are in the press: Nos. 207, 208, 209, 213, 216, 217, 218, 219, 225, 226, and 228.)

IV. ANIMAL HEALTH AND PRODUCTION INVESTIGATIONS.

1. *General.*—During the year progress with the work planned and to be financed from funds from the Wool Research Trust Account has been disappointing. This work calls for new facilities, particularly laboratory accommodation at Prospect, and at Armidale, New South Wales. Materials and labour have not been available to provide these facilities. Financial assistance, given in the past by the Australian Wool Board, was obtained, by virtue of the new provisions, from the Wool Research Trust Account. The continued financial assistance which was received from the Australian Cattle Research Association, from the George Aitken Pastoral Research Trust, and from the Queensland Government greatly facilitated the work of the Division.

At every turn, during the year, difficulties have arisen in all branches of the work mainly because of shortage of accommodation, of supplies, and of personnel. The Fleece Analysis Laboratory has been housed temporarily at Villawood, New South Wales, and the Wool Biology Section at 17 Randle-street, Sydney. Some reconstruction of two laboratories in the McMaster Animal Health Laboratory was carried out and arrangements were made with the University College at Armidale (New South Wales), by which about 4 acres of land were made available for the construction of Regional Laboratory buildings. When ready, these will be occupied by officers of the Division and of the Division of Plant Industry. Negotiations took place for the purchase of about 4,500 acres of land near Armidale for the establishment of the main Field Station for the regional centre. These were not completed at the end of the financial year. An area of 115 acres at Prospect Hill, near Parramatta, was acquired in August, 1946. This is reserved as the site for a sheep and wool research laboratory to investigate the physiology of the sheep under intensive controlled conditions. The laboratory will also house the Fleece Analysis Unit.

Plans for the development of the work on animal breeding, genetics, and animal production were advanced during the year.

As in the past, the work mentioned in the following paragraphs is described mainly under the principal laboratories and field stations, although health and production studies are interwoven, as are those being carried out in co-operation with other Divisions of the Council and with Departments of Agriculture in the several States.

2. *Animal Health Research Laboratory, Melbourne.*—(i) *Pleuropneumonia of Cattle.*—The experiment designed to determine the influence of nutritional stresses on the maintenance of immunity against pleuropneumonia continued. It was found difficult to lower the plane of nutrition to suitable levels under grazing conditions at Tooradin. The results to date do not show a significant depression of immunity to infective aerosols. During the year 314,000 doses of vaccine were distributed to centres in Queensland and the Northern Territory mainly. Antigen for the complement-fixation test was supplied to Kenya as in the past.

(ii) *Diseases due to Clostridia.*—Attention was given to the classification of the *Cl. oedematiens* group by means of the toxic fractions recognized by Oakley and Warrack in England. Using antisera provided by them, it has been possible to classify strains as Type A or Type B on the basis of toxic factors produced. All the black-disease strains, previously classified on other grounds as belonging to Type B, have been shown to produce beta-lecithinase and in many cases zeta-haemolysin, and are accordingly confirmed as Type B. The strain isolated in 1928 by Bull from "swelled head" in rams produces gamma — and epsilon-lecithinases with delta-haemolysin and is accordingly classified as Type A.

Attention was given to two toxic fractions of *Cl. welchii* referred to as eta and iota. Strains producing the iota fraction have been claimed in England to produce a type of enterotoxaemia. Strains previously isolated from cases of enterotoxaemia in Australia, but incapable of producing the characteristic epsilon toxin of Type D strains, were examined for capacity to produce iota toxin but with negative results. The same was true of Type D strains examined, and our various *Cl. welchii* antisera did not contain detectable iota antitoxin. Therefore there is no evidence so far that *Cl. welchii* Type E exists here. In an earlier publication it was reported that trypsin increased the toxicity of epsilon toxin through a digestive effect upon inert epsilon prototoxin. It has now been found that this activation is produced both by pure crystalline trypsin and chymotrypsin received from Dr. Northrop, United States of America. This finding invalidates earlier speculation as to the nature of the masking groups.

(iii) *Caseous Lymphadenitis of Sheep.*—Further experiments were started on an investigation of the protective value of annual vaccination one month before shearing. The value of placing sheep directly "off shears" into a clean, rested paddock is also being investigated. During the year a survey of the occurrence of the disease in the Eyre's Peninsula district of South Australia was carried out in co-operation with the Department of Agriculture.

(iv) *Tuberculosis of Cattle.*—The complement-fixation test has been more extensively studied using several antigens, and the reactions of sera from tuberculosis-free herds have received special attention. The results have indicated that adjustment of the diagnostic titre

to a level necessary to minimize false positive reactions in animals free from the disease leads to a marked reduction in the numbers of tuberculous cattle detected. Interesting academic observations have been made, and the work is being continued in the hope of finding a practical application of the test in the detection of cattle which, while not reacting to the tuberculin test, are heavily infected and are dangerous spreaders of the disease.

(v) *Mastitis in Dairy Cattle.*—The main experimental herd at Werribee is still under supervision. The three small herds mentioned in the last report have been incorporated in other herds; none of the group which were introduced into an infected herd to test their susceptibility developed clinical mastitis, and there were only six occasional infections, but this might have been related to the fact that penicillin treatment of the infected herd had greatly reduced the opportunities for infection of the introduced group. Further observations on the possibility of calfhood infection by *Str. agalactiae* by means of infected milk are being carried out on animals which were removed from their mothers at birth, one group being then fed on infected milk and the other on sterilized milk. Since weaning they have been run together, and three have recently come into production.

In an investigation of the effect of hygienic precautions upon the incidence of *Str. agalactiae* on the surface of teats, this organism was isolated from 46 per cent. of the teats in a herd in which hygiene was of a very low standard and from only 3 per cent. and 17 per cent. (two examinations at an interval of eight weeks) in a herd where hygiene was good. In this milking shed, extensive examination of the apparatus, fittings, and utensils revealed the organism in only one instance (handle of a water tap) out of 39 objects tested. Furthermore, only two swabs out of 50 taken from the vaginal and perineal regions of the cows were positive, and one from a milker's hand. In the same herd over a period of nine months, no significant difference was found between the incidence of infection among 276 hand-stripped quarters and among 128 machine-stripped quarters (29 and 30 per cent. respectively); similarly the incidence of infection on the teats did not differ significantly in the two groups (18 and 14 per cent. respectively). In an attempt to eliminate *Str. agalactiae* from the teat surfaces, hypochlorite solution (1250 p.p.m. available free chlorine) was compared with an ointment containing 0.1 per cent. of trypaflavine and 555 units of penicillin per gram in a mixture of equal parts of soft paraffin and wool fat. After treatment after each milking for fourteen days, there was no significant difference between the incidence of infection with each treatment or between these and previous experience in the same herd. A peculiar feature, which has frequently been observed with strains of *Str. agalactiae* isolated after exposure to various antiseptics, including crystal violet, was again encountered after this test: all the strains isolated after treatment and examined, although they reacted with the group B precipitin test, failed to agglutinate with any of the type antisera, thus suggesting some injury to the mechanism which synthesizes the type substance.

In the same well-managed herd, it has been found impossible to eliminate *Str. agalactiae* completely by successful penicillin treatment of all clinical and of all persistent subclinical cases; although clinical mastitis was prevented from developing, subclinical infections, usually slight, continued to appear. An attempt was then made to eliminate infection completely by frequent bacteriological examination followed by standard penicillin treatment of all infected quarters. This also failed. Finally every quarter of every cow in the herd was simultaneously treated without regard to infection. In spite of this intensive treatment rare infections still appeared at intervals beginning a fortnight after treatment. The herd is still under observation. On the other hand, in another herd a similar total-herd treatment was successful, *Str. agalactiae* being completely eliminated. It is of interest that a commercial herd was examined which was naturally completely free of *Str. agalactiae* (but not of micrococci, staphylococci, non-group B streptococci, or diphtheroids) and of any evidence of mastitis.

The new acridine antiseptic 1-methyl-5-aminoacridine ("salacrin"), described by Albert and Rubbo, was found to be too irritant for use in the udder; 4,4′-diaminodiphenylsulphone ("sulphone"), introduced by Imperial Chemical Industries and recommended by Francis, is being tested against staphylococcal infections but so far has not shown itself to be outstandingly successful.

(vi) *Toxaemic Jaundice in Sheep.*—The investigation has continued with the co-operation of officers of the Veterinary Research Station, Glenfield (New South Wales), and of officers of the Divisions of Soils and of Plant Industry. The incidence of the disease was low in the Murray Valley during the dry period. Severe outbreaks occurred under early and high rainfall conditions in Victoria and New South Wales. These were associated with the luxuriant growth of subterranean clover brought about by the early rains. Observations have indicated that soil acidity provides conditions favorable to the occurrence of the disease in sheep. More evidence has been obtained on the importance of plant species. Conditions which favour herbage as against grass have been associated with the occurrence of the disease. Some herbage plants show a high uptake of copper and a low uptake of molybdenum, and these seem to favour a high copper status in the sheep. Three species of plants were studied at several levels of pH of the soil in pot experiments. Studies on copper assimilation by sheep under pen conditions were continued. A more detailed report has been submitted to contributing bodies by the Investigation Committee.

(vii) *Haematuria Vesicalis of Cattle.*—The analytical methods for estimating groups of urinary phenolic bodies, referred to in the last report, based upon spectrophotometric estimation of azo dyes prepared from the various phenols, have been further improved, and systematic observations have been continued. Suggestive differences have been found between the urines of cattle from affected and those from non-affected areas, but many more examinations will be required before reliable conclusions can be drawn.

(viii) *Contagious Abortion of Cattle.*—The experiment designed to test the resistance of vaccinated calves to natural infection has been concluded. It supports the claims that vaccination with *Br. abortus* "Strain 19" vaccine prevents both infection and abortion: only one of 27 vaccinated heifers subsequently became infected and aborted whereas eighteen of 29 unvaccinated heifers became infected; of the eighteen, ten aborted and three others excreted virulent *Br. abortus* in the discharges. Only one of 30 pregnant heifers, which had been vaccinated intracaudally and were exposed in the same environment, became infected and aborted. A study on the various factors influencing viability of *Br. abortus* "Strain 19" vaccine was completed for publication.

The investigation into the cause of deterioration of vaccine was concluded. Important factors were (*a*) intrinsic peculiarities of particular substrains which affected the initial pH of suspensions and the optimal incubation period, and (*b*) toxic substances leaching from rubber vaccine caps, particularly if they were manufactured from red-rubber mix containing about 20 per cent. of zinc oxide, if they had been prepared by

acid-washing, and if they were repeatedly autoclaved. Freezing was also found to be highly lethal. The results of this investigation are being prepared for publication.

(ix) *Toxicity of Wheat for Stock.*—The repeated administration of the antihistamine drug Neoantigan, N-dimethylaminoethyl-N-P-methoxybenzyl S-oc-amino pyridine, at the rate of 2 mg. per kg. body weight to horses and sheep which had gorged upon wheat had no significant effect in preventing laminitis. This finding, taken in conjunction with the earlier experimental results, makes it unlikely that histamine plays an important part in wheat intoxication. The possibility of excessive production of lactic acid is being considered. A publication is being prepared. The decarboxylating enzymes of the Lactobacillus referred to in the last report are being studied in greater detail at the Biochemistry Laboratory at Cambridge, England.

(x) *Anaplasma centrale and Haemobartonella bovis.*—The strains have been propagated in calves and maintained at —78° C. Splenectomy of infected calves was followed by an intense infection with *H. bovis,* with minor symptoms, and rapidly responded to penicillin therapy.

(xi) *Effect of Administration of Thyroxin on Cattle.*—Examination of the materials collected at autopsy is almost completed and the results will be submitted for publication.

(xii) *Effect of Long-continued Cutaneous Application of DDT Oily Solutions to Cattle.*—The experiment referred to in the last report is being continued. The animals have shown no signs of intoxication. Five have borne calves which are suckling their mothers without obvious harm. Samples of milk are being analysed for DDT by the Section of Dairy Technology. Present indications are that excretion is very low, of the order of 3-4 p.p.m.

(xiii) *Bacterial Oxidation of Arsenical Cattle-dipping Fluids.*—Three distinct types of Gram-negative organisms capable of oxidizing arsenite to arsenate in the presence of oxygen have been isolated, two being active at temperatures up to about 25° C., the other up to 37° C.

(xiv) *Physiology of Reproduction.*—(*a*) *Reproduction in the ewe.*—Two studies have been in the course of development: (1) a study of the nature of cyclical activity in the reproductive tract of the mature Merino ewe, and (2) a study of the development of this activity in the young ewe, and the influence on this development of the time of the year at which the lamb is born. An even line of ewes of medium-fine woolled type from a Western District flock has been procured for the first study. They have been accommodated at Werribee, where preliminary observations on them have beeen initiated. To provide the lambs for the second study, ewes of a medium-fine woolled type from the Riverina have been obtained. These ewes have been divided into groups to be mated at different times of the year. The first of these matings has been completed.

(*b*) *Changes in the reproductive tract of guinea pigs consuming subterranean clover.*—A study has been made of changes in the reproductive tract of virgin female guinea pigs following the consumption of dried subterranean clover of the Mount Barker strain from a property at Heywood, Victoria, on which breeding troubles among sheep have been experienced. The consumption of clover from this sample had previously been found to produce changes in the endometrium of entire females of a similar nature to those observed by Western Australian workers with Dwalganup subterranean clover from "affected" properties in Western Australia. In ovariectomized young virgin females it produced oestrous changes in the vagina and a marked increase in the weight of the uterus and in the activity of the uterine glands. A great proportion of the increase in weight of the uterus occurred within two days and there appeared to be little further increase after eight days. The degree of increase during the first two days was found to be related to the quantity of clover consumed over a limited range of consumption.

An attempt is being made to develop a method of assay of the active material in clover on the basis of these changes in uterine weight.

3. *McMaster Animal Health Laboratory.*—(i) *Parasitological Investigations—Internal Parasites.*—(*a*) *Study of action of phenothiazine against Haemonchus contortus.*—It was found that when doses from 2.5 g. to 12.5 g. are injected directly into the rumen of infested sheep, although egg production by the parasite is greatly reduced for a time there is very little destruction of the worms. With the smaller doses there was no anthelmintic effect and the egg production by the parasite returned to normal in a few days.

(*b*) *Study of action of phenothiazine against Trichostrongylus spp.*—Efficiency trials have shown that with an increase in dosage to 59 g. and beyond, the anthelmintic action of phenothiazine is increased. The results have shown that in the treatment of trichostronglosis the date rate should not be allowed to fall below 25 g. for sheep ten to twelve months old.

(*c*) *Phenothiazine against Oesophagostomum columbianum.*—Phenothiazine was found to be less effective in the treatment of "pimply gut" when used as an enema than as a drench. The results of the studies with this and other verminous infestations suggest that factors other than the concentration of the drug in the vicinity of the parasite are concerned in the efficiency of the treatment.

(*d*) *Study of infestation of the bowel by larvae of O. columbianum.*—Infested sheep were kept under conditions which prevented re-infestation. They were treated periodically with phenothiazine to remove all adult worms. It was found that adults continued to emerge from the nodules in the bowel wall for many months, a few were still emerging after a period of twelve months but observations are not completed. As larvae in the bowel wall are not affected by anthelmintic treatment, it is obvious that control methods must be prolonged in any campaign against the infestation.

(*e*) *Effect of fasting of the host on egg production by worms.*—Factors affecting egg production must be considered when anthelmintic efficiency is to be judged by faecal egg counts. It was found that fasting the sheep for four or five days reduced egg output for several days thereafter. The effect upon *Trichostrongylus* was greater than on *Haemonchus,* probably because of their different feeding habits. Dosing with phenothiazine reduced food consumption by the sheep but appetite returned to normal within a week.

(*f*) *Nutrition and resistance to worm infestation.*—(1) Two groups of young sheep, naturally infested with *Trichostrongylus* spp., *H. contortus,* and *O. columbianum* were kept in pens, and one fed on a ration which caused a gain in weight, and the other on a ration which approximately maintained the initial body weight. The period required to throw off *H. contortus* was 6-43 days (mean 19.2 days) among those on the better diet, and 12-120 days (mean 57.1 days) among those on the poorer diet. When subsequently dosed with infective larvae, those on the poorer diet proved highly susceptible, whereas those on the better diet were relatively resistant. The group on the better diet also tended to throw off their trichostrongylous infection, but any effect of the diet upon nodule worm infection was obscured by the continued emergence and development of larvae during the period of observation. Further experiments are being planned.

(2) The results of administering infective larvae of *H. contortus* experimentally to sheep already carrying an established infection are variable: sometimes the established infection is thrown off, but is soon re-established by adults developing from the infecting dose of larvae; sometimes no re-establishment occurs. Field observations indicate that similar phenomena occur naturally and when the infestation is thrown off the phenomenon is referred to as "self-cure". A group of infected sheep was divided into two groups, one being left on pasture and the other brought into pens at the laboratory. "Self-cure" subsequently occurred among those at pasture, whereas infection persisted among those in the pens.

Further observations on "self-cure" were made near Armidale. Sheep on three properties, each about 10 miles from the other, were kept under observation by faecal examination. "Self-cure" occurred at the same time in the three groups in December and again in February. Experiments have shown that the sheep have no appreciable resistance to infection at the time "self-cure" is manifested and that the phenomenon is of very short duration. Present indications are that it is probably an anthelmintic effect rather than a form of immunity or resistance.

(3) A further trial of the value of green oats for winter grazing by weaners in New England, conducted by the Armidale laboratory, confirmed the results of the previous year. Weaners which grazed continuously on green oats from May to September gained over 26 lb. per head, none died, and only a few showed any detectable infection with nodule worm at the end of the trial. Those on green oats for two or three hours a day and on natural grazing at other times, only gained 1.3 lb. per head, cut over 2 lb. less wool per head than the continuous-oats group and did not lose their *O. columbianum* infestation. The groups on natural grazing, including one group which was drenched periodically with phenothiazine, lost weight and suffered heavy mortality. Over 12 per cent. of the drenched group died and nearly 50 per cent. of the undrenched group. The great advantage of a high plane of nutrition for weaners during their first winter was further shown by retaining from the 1945 trial groups of sheep which had been on oats and natural grazing, respectively, during their first winter. At shearing in 1946, those which had spent the 1945 winter on oats cut 1 lb. 10 oz. more wool and weighed about 9 lb. more than those which had spent the 1945 winter on natural grazing.

(*g*) *Studies on Limnea brazieri.*—Copper sulphate is well known to be highly toxic to this snail, the intermediate host of the liver fluke. It has been found that it is the free copper ion which is toxic. Copper salts with other acid radicles are just as effective as the sulphate, but compounds in which the copper is masked or protected, e.g. by ammonium groups, are much less effective. When copper sulphate is added to some natural waters in fluke-infested areas a precipitate is formed which reduces the efficiency of the quantity of copper sulphate which has been used. Several other chemicals were examined for toxicity to *L. brazieri,* including rotenone, which was quite ineffective after long exposure at 1/10,000, but none approached copper sulphate are being investigated. Examination of the approximately half as toxic as copper sulphate. Methods of draining more effectively those areas in which *L. brazieri* persists despite treatment with copper sulphate, are being investigated. Examinaton of the snail's crop content confirmed that it feeds upon diatoms and species of Desmidaceae. Inorganic material which is ingested remains in the crop for several days and probably aids in grinding up the organic matter taken in as food. *L. brazieri* is non-operculate and hence susceptible to desiccation. Large numbers die when their habitat dries out. Direct sunlight also is quickly lethal, but these snails can survive for long periods in places which remain moist and are sheltered from sunlight. It is thought that the holes made by "yabbies" (*Parachaerops* spp.) enable many snails to survive over prolonged dry periods. No evidence has been found that they burrow into the ground when pools and creeks dry up. There is a well-marked oviposition period in the late winter or early spring. A second such period occurs about mid-summer, but relatively few eggs were produced during the period of observation. Prolonged exposure to temperatures about freezing point appear to be unfavorable to this species and none could be found above 5,000 feet on Mount Kosciusko in February, although many favorable habitats were present. The possibility that *Limnea lessoni* may serve as an intermediate host of the liver fluke is being investigated. The observations by earlier workers that rabbits may be heavily infested with liver fluke has been confirmed.

(*h*) *Helminth physiology and toxicology.*—Studies on the physiology of worms, with a view to finding vulnerable points for attack on them, have been continued. Studies on the uptake of oxygen and the production of carbon dioxide by eggs, larvae, and adults of *H. contortus, N. muris,* and *A. galli* showed that all stages could utilize oxygen when it was available. The methods of use of oxygen indicated that adult forms of the larger species used sugars for energy production, whereas larvae were dependent on fat as a source of energy. Study of the localization of alkaline phosphatase in the cuticle of the sheep tapeworm suggests that inhibitors of this important enzyme should have a toxic effect on the worm. Radio-active phosphorus was used to examine the uptake of phosphorus in two species. They were found to have a high demand for phosphate. Preliminary studies on the mode of action of phenothiazine showed that it inhibits an enzyme, acid phosphatase, of the parasite's tissues. Further study of this problem awaits receipt of radio-active sulphur. Sheep nematodes were shown to produce amines which may be toxic to the host. The effects of nematode infestation on the physiology of the host's intestine is being studied.

(*i*) *Immunity and resistance phenomena in nematode infestations.*—A complement fixation test has been developed, using antigens prepared from *H. contortus* and *Trichostronglus spp.* and having low anticomplementary and moderate combining power. Results of tests on selected sheep of known history suggest that this test may be of considerable value in tracing the rise and decline of residence to parasitic infections. There is considerable cross reaction between antigens prepared from *H. contortus* and *Trichostrongylus* spp. Attempts to prepare antigens from larvae have not yet succeeded. Fractionation of adult worm material used as antigen indicates that the lipoid fraction is of particular importance in the complement fixation test, whereas skin reactions to intradermal injections are smaller, but considerably more specific, when the polysaccharide is used.

(*j*) *Administration of phenothiazine in salt licks.*—Continuation of this work has shown again that the quantity of phenothiazine ingested was too small to have any appreciable anthelmintic effect. Moreover, phenothiazine staining of the fleece occurred to a marked degree.

(*k*) *Epidemiology of helminth infections of sheep.*—Observations have continued at Saumarez, but drought compelled several co-operating graziers to cease the trials temporarily. It is hoped to commence again shortly on these and other properties.

(ii) *External Parasites of Sheep.*—(*a*) *Control measures against lice and keds.*—Earlier work had shown that when emulsions of DDT were used as sheep dips, the dispersed phase was "stripped out" as

dipping proceeded. DDT analyses on dip-bath samples as made at several institutions appeared to be inconsistent. A method which gives consistent results was evolved in the laboratory. The usual dehalogenation technique is used, but the residues precipitated from dip samples are dried at less than 60° C. to avoid loss of DDT. Also, owing to the low concentration of DDT in the dip bath, a considerable volume must be taken for analysis. Preliminary tests were then made to discover the rate of "stripping" from emulsions of finer and coarser dispersed phase and from suspensions of DDT in the form of dispersable powders. This work is still in progress. Current results suggest that the rate of stripping does differ with different formulations, but that it tends to be proportional to the number of sheep passed through the dip.

A series of field dipping trials was carried out, using Rucide (a proprietary DDT preparation) in six flocks involving some 10,000 sheep. Both plunge and shower dips were used. In plungs dips, concentrations of 0.1, 0.07, 0.04, and 0.03 per cent. para-para-DDT were used and in shower dips 0.1 per cent. Keds were eradicated from both newly-shorn sheep and woolly lambs in plunge dips with 0.1 per cent. pp'-DDT, but at 0.03 per cent., although infestation was eliminated from the newly-shorn sheep, it persisted in the woolly lambs, probably due to poor wetting. One flock of shorn sheep which was dipped in 0.1 per cent. pp'-DDT was carrying a light infestation with body lice (*B. ovis*) which the dip eliminated. In the trial with a shower dip "stripping" took place more quickly. Although 0.1 per cent. pp'-DDT was used, it gave only a partial kill of keds on woolly sheep after the first 1,000 head had passed through the dip, but still eliminated keds from newly-shorn sheep.

(*b*) *Bionomics of the sheep foot-louse* (*Linognathus pedalis*).—Considerable difficulty has been experienced in keeping the parasite alive under artificial conditions or in transmitting it from affected to unaffected sheep. Nevertheless, close observation on infested sheep has enabled the life cycle to be determined tentatively as follows:—Deposition of egg to hatching—14 to 15 days; 1st stage larva to adult—16 or 17 days; pre-ovi-position period—5 days; egg to adult—30 to 32 days; rate of egg production—approximately 1 per day. These results, however, are based on complete observations of relatively few lice and need thorough checking before acceptance. The work is continuing and observations are being made at monthly intervals on an infested flock of Romneys near Sydney. The degree of infestation is generally heavier in younger sheep. Lambs as young as 4 months were found to be heavily infested. A slight decline in infestations was observed in the autumn with a tendency to increase again in the early winter. Tests are being made as opportunity offers, to determine the value of arsenic, rotenone, DDT, and Gammexane for the control of this parasite.

(*c*) *Nutrition and resistance to external parasites.*—Eight sheep were each infested with 10,000 lice (*B. ovis*) in June, 1946. These sheep also carried a light infestation with keds (*M. ovinus*). After one month the infestations of *B. ovis* on all of them had declined considerably. The sheep were then divided into two groups which were placed on high and low planes of nutrition, respectively. The infestation of the sheep on the poor diet was still at a low level when they were shorn in January, but has increased since so that they now show about the same degree of infestation as at the beginning of the trial. The infestation of the sheep on the high plane of nutrition fell rapidly and after three months the sheep were virtually clean. They have remained so ever since. Ked populations in the two groups have shown similar trends to the louse populations. Sheep on the poor diet gained 7 lb. in 12 months; those on the good diet gained some 68 lb. in the same period.

(iii) *Blowfly-Strike Problem.*—(*a*) *Modified Mules Operation, Optimum Tail-length, and Surgical Treatment of Tails.*—No further trials have been undertaken during the year, but co-operative observations with officers of the New South Wales Department of Agriculture are being made in a trial at the Experiment Farm, Trangie, to compare the efficiency of the modified Mules operation plus medium-long tails, modified Mules operation plus shorter tails treated surgically, and the Manchester treatment.

(*b*) *Studies on Body-strike.*—Observations which commenced last year on a property near Stanthorpe are continuing. Association between so-called fleece-rot and body-strike was confirmed; last year approximately 1.0 per cent. of strike occurred among sheep showing no fleece-rot compared with about 22.0 per cent. of strikes among sheep showing severe fleece-rot. Sheep showing fleece-rot in 1946 are tending to show it again in 1947. When the sheep were classified visually for "density", it was found that fleece-rot was more prevalent among dense sheep than among those with very slack fleeces. This was observed also among the sheep at the McMaster Field Station, and is noted because it is contrary to the usual belief. No other marked correlations are yet apparent between fleece-rot and fleece characteristics.

(*c*) *Lamb-marking dressings.*—Previous trials having shown that a lamb-marking dressing containing boric acid, citronella, and bentonite was highly effective in preventing strikes of the marking wounds, the quantity of dressing which must be used to ensure efficiency was next investigated. As a result, it may be said that, although results depend to some extent on fly activity, the number of lambs dressed should not exceed 100 per gallon. If flies are relatively inactive, the dressing may be effective when used more sparingly, but fly activity cannot be predicted with sufficient confidence to recommend this. It appeared that the efficacy of the dressing was almost certainly due to the repellent effect of the citronella oil which it contained. In further trials, using the boric acid-citronella-bentonite dressing as a standard, a similar degree of protection was afforded by spraying the tail and crutch with pure citronella oil, semi-natural citronella oil (i.e. citronella oil from which most of the geraniol has been removed), or dibutyl phthalate. The quantity used was approximately 2.5 ml. per lamb. B.K.B. blowfly dressings were tested again in this series and proved relatively ineffective. Blowflies were not particularly active during these trials, which must be repeated and extended to include other repellents. If present conclusions are confirmed, citronella oil would prove a highly economical dressing for this purpose.

(iv) *Biochemical Studies.*—Work has been hindered by long delays in necessary alterations to the laboratory and the absence of one of the two senior workers on post-graduate studies overseas. Much accumulated information has been checked and prepared for publication.

(*a*) *Studies on mineral metabolism of sheep.*—No new experiments were undertaken. The results of several years' work are being prepared for publication.

(*b*) *Analytical Studies.*—Methods for estimating serum magnesium are being critically examined. The effects of storage, temperature, and transport of blood and serum samples on the level of serum inorganic phosphate have been investigated. Accurate serum inorganic phosphate values can be obtained provided the samples are held at not more than 20° C. and the serum is removed from the clot within 24 hours. At higher temperatures, e.g. 37°C., the serum should be

removed within 5 hours of collecting the blood sample. If analysis cannot be completed within 24 hours of removal from the clot the serum should be deproteinized. Deproteinized filtrates showed no change in inorganic phosphate even after 24 hours at 37° C.

(*c*) *Studies on poisonous plants.*—Samples of spurry (*Spergula* spp.) and mouse-eared chickweed (*Cerastium glomeratum Thuill.*), alleged to have been concerned in an outbreak of acute hypocalcaemia among ewes in Tasmania, were found to contain only 1.60 and 1.02 per cent. anhydrous oxalic acid respectively. These samples, however, had been collected several weeks after the outbreak occurred.

(*d*) *Effect of vitamin D supplements during winter, on body weight and wool production of weaners in southern latitudes.* — In southern latitudes, sunlight lacks effective ultra-violet rays for several weeks during winter. Under these conditions weaners in New Zealand have benefited appreciably from vitamin D supplements. A series of controlled experiments has therefore been commenced, ranging from Tasmania to New England. The effect of massive doses of vitamin D (calciferol) will be examined at these different latitudes as regards live weight increases, wool production, and the serum calcium and phosphorous levels.

(v) *Endocrinological Studies.* — (*a*) *Studies on oestrogens.*—Ewes produce oestrogen, a female hormone, at appropriate periods. These are destroyed in the body or excreted. Substances which have similar action but which are not easily destroyed in the animal body are produced by some plants, and some such substances have been synthesized in the laboratory. Studies have been made on the excretion of natural oestrogen in the urine and faeces of sheep. Studies have also been made on the oestrogens produced by plants and their destruction by enzymes produced by some species of plants. Groups of wethers on high and low protein diets were injected with hexoestrol, a synthetic oestrogen, over a period of three months. Changes in the bulbo-urethral glands, the udder and skin glands, and in the prepuce were studied. Continued treatment with the oestrogen failed to maintain mammary enlargement of skin gland activity. The wethers on the high protein diet quickly developed external ulcers on the prepuce but the ulcers healed quickly in those receiving hexoestrol whereas they persisted in the control group.

(*b*) *Studies on gonadotropins.* — Human castrate urine is rich in gonadotropins but, except on one occasion, the urine of wethers has given negative determinations. The possibility that castrate sheep may destroy or inactivate such hormones will be investigated. Takadiastase destroys gonadotropins, but no clear cyclic change in blood diastase has been detected with sheep and the level is not grossly affected by sex hormone injections or castration.

(vi) *Wool Biology.* — (*a*) *Study of production factors in two contrasting types of sheep.*—An intentive study was made of fine-wool Camden Park Merinos and Corriedales. Groups of each type were maintained (i) at a uniform level of feeding, (ii) on a low plane, changing by stages to a high plane, and (iii) on a high plane, changing by stages to a low plane of nutrition. The sheep were housed in single pens and very frequent and detailed observations were made. From the information obtained it is hoped to establish the conditions necessary to assess critically the production performance of breeds and strains of sheep in comparative studies. The Corriedales and Camden Merinos reacted to nutritional changes very differently in some important respects, and differences in wool growth depending on temperature, existing fleece growth, and other factors became apparent. Detailed results are in preparation for publication.

(*b*) *Responses of sheep to high temperatures and humidities.*—Some Corriedales and Camden Merinos, already studied intensively in the previous experiment, were transferred to the Physiology Department of the Queensland University, where their reactions to long and short periods of exposure to various high temperatures and humidities are under study.

(*c*) *Skin cancer in sheep.* — A peculiar form of epithelioma in a strain of Merino, which appears to have a strongly inherited tendency to the development of such tumours, is being studied in association with the Sydney University School of Veterinary Science.

(vii) *Studies on Fertility in Rams.—The effect of diet on spermatogenesis.*—The effect on spermatogenesis of high and low planes of nutrition, with and without supplements of carotene, is being studied on several groups of rams. Blood vitamin A values are now declining in rams not receiving carotene supplements, the decline being greater among rams on a high plane than on a low plane of nutrition. Abnormalities in ejaculated sperm are increasing accordingly with vitamin A deficient animals despite the high plane of nutrition. During the summer months both the number of spermatozoa ejaculated and their longevity diminished but rose again with the onset of winter. During the summer months when high temperatures appeared to affect spermatogenesis adversely, the proportion of abnormal spermatozoa reached 40 per cent. in some rams on the low plane of nutrition, irrespective of carotene intake. All rams again gave normal sperm in the early winter, but latterly, as blood vitamin A levels have declined, some rams in the high plane group, receiving no additional carotene, are again showing an increasing number of abnormal spermatozoa.

4. *The F. D. McMaster Field Station.*—(i) *General.*—Approximately 23 inches of rain were recorded as falling at the station during the year; 19 inches fell between November, 1946, and April, 1947. The winter was again dry, and the seasonal conditions favoured summer crops and pastures rather than cereals. During the year, 100 acres of oats, 60 of millett, and 16 of phalaris and subterranean clover pasture were sown.

At the end of the year the sheep at the station consisted of 97 rams, 174 wethers, and 747 ewes. Lambs reared during the year totalled 318 from 497 ewes. For the 1947-1948 season, 560 ewes were mated. Cattle numbers were increased to 24. Consequent on the purchase of a tractor, draught horses have been reduced to 3. One light horse has been maintained.

(ii) *Inheritance of Skin Wrinkles in Sheep—The* investigation of the method of inheritance of wrinkling of the skin of sheep has shown the characters "wrinkledness" and "plain body" to be paired in the Mendelian sense. Among sheep for which environmental factors were controlled, the characters were determined to depend upon the action of many genes, among which those for plain body displayed dominance. The evidence indicated, however, that underlying this clear-cut dominance there were quantitative effects. The investigation also disclosed that whereas in sheep such as those under observation, it would be relatively simple to evolve either very plain or very wrinkled animals, control of intermediate types would be rendered difficult by their heterozygosity. Experimental matings which are now in their third repetition have, on the two earlier successive occasions, disclosed little, if any, relation between the appearance of Merino sires and the degree of wrinkledness of their progeny from first-cross, heterozygous ewes. Although there was no significant difference between the progeny from crossbred ewes, of four out-bred Merino sires graded from 25 to 5 with respect to wrinkling (maximal score 27), the progeny of all four were different from those of an inbred sire whose wrinkling score was 2. In

the second repetition of this experiment the ewes were re-randomized, and 4 rams, different from those of the first experiment, were used.

(iii) *Study of Inbred Merino Flocks.*—Three flocks of inbred Merino sheep have been established. The first flock consists of 31 ewes. The second started with 100 stud bred ewes and one ram: the progeny have been divided into three sub-groups. The third flock of 94 ewes consists of two sub-groups headed by sires that are half-brothers. The number of inbred lambs is as yet too few to permit close statistical analysis of results. However, comparison of birth-weights indicates that there is no decline until an inbreeding coefficient of about 25 per cent. is reached. At this level there is a fall of 15 per cent. in the birth-weight of inbred lambs compared with those not inbred. No major defects have yet been disclosed, but several lambs either without or with only rudimentary external ears and other lambs born dead with stiff joints have been observed.

(iv) *Polledness in Merino Sheep.*—Since 1939 a flock of Merino sheep has been maintained to investigate the inheritance of polledness. It was begun with a ram A.992 which had scurs three inches long. Two of his sons, B.308 and B.320, and other progeny were selected as most nearly having a "depression" at the horn site. In 1943, an unrelated ram, C.294, with a scur about half an inch long, much smaller than had been previously observed, and one depression, was introduced. At the same time, the ewes were severely culled until only those with full "depressions" remained. This intensive selection toward polledness in parents has now given rise to three 4-tooth and two 2-tooth full-depression rams, all sons of C.294. In 1946, C.294 was replaced by his son, C.654, a ram which had full depressions at the horn site. None of this ram's progeny had any horn development beyond a scur of under two inches in length, and among them was a male lamb with full depressions. Two other sons, C.860 and C.873, were progency-tested for the homozygous hornless state by mating them with knobbed and horned Merino ewes. Neither ram left male progeny with full depressions, thus showing themselves to be heterozygous. However, neither ram begot any horned male progeny, the nearest approach to hornedness in 21 male lambs being one lamb which has scurs less than two inches long.

All the three rams, C.654, C.860, and C.873, are the result of three generations of selective breeding for the polled character. This accumulation of the completely polled characterization is being associated with the conception of "building up of dominance". Evidence provided by the progeny test on C.860 and C.873 supports this view. Had there been no accumulation of the genes for polledness, or had inheritance of the condition been on a simple Mendelian basis, a much wider range of characterization would have been evident in their progeny from knobbed and horned ewes.

(v) *Studies on the Inheritance of "Hollowback", "Hairiness" or "Fluffy-tip", and "Parrot Mouth".*—These studies have been continued and data are being built up but are still incomplete.

(vi) *Development of Hybrid Dairy Cattle.*—The small Zebu cross-bred dairy herd consists of two half-bred bulls, two and three years old respectively, two quarter-bred Zebu x Jersey heifers and one bull, and one three-quarter Zebu x Jersey heifer. The herd of European dairy cattle consists of six Jerseys, five Red Polls, and three milking Shorthorns to be used in crossing. The herds are under production tests.

(vii) *External Activities.*—(*a*) *Survey of wool production.*—During the year intensive study was given to the evolution of methods of defining the conformation and the fleeces of sheep to be used for survey purposes and for animal breeding investigations. Body shape is determined from a series of five measurements. The fleece is sampled on the sheep at three positions spaced from front to rear and lying on a diagonal line approximately from the hip bone to the point of the elbow. The measurements, scoring systems, and sampling procedure, which have been applied to over 1,500 sheep, can be carried out at the rate of approximately 150 per day for either measuring and scoring or sampling and scoring. Thus the techniques are applicable to the large numbers of sheep to be sampled from the populations encountered in the conduct of the survey. The first part of the survey is being carried out in New South Wales on flock sheep in a range of environments broadly classified by their major plant associations.

(*b*) *Animal breeding investigations at "Gilruth Plains".*—These studies are outlined in Section 5.

(*c*) *Zebu hybridization. Co-operative investigations.*—In 1941 the original agreement, between the Council and co-operators in the Zebu cross-breeding experiment, was modified to permit syndicate members to sell approved breeding cattle to persons who were not members of the co-operating group. In 1947 the original centres were visited after a lapse of six years, and recession or expansion of the project was determined. Four of the early experimental centres—Glen Prairie, Waverley, Wairuna and Ingham—are in the coastal belt of Queensland cattle country. All their owners continue enthusiastically with cross-breeding on their own properties, and all have made sales of approved breeding cattle. These drafts, of from single animals to 40 head, have been scattered throughout the coastal and near-coastal country from Rockhampton to Coen, high up on Cape York Peninsula.

Expansion has been greater in areas where holdings are relatively small and where tick abundance necessitates repeated handling of the cattle. On more extensive holdings, wildness of the cross-breds has restricted their usefulness. Previous observations with respect to tick repellence, hardiness, and carcass weights and quality were confirmed. It was estimated that the original nineteen head of imported animals had multiplied and produced cross-bred progeny which number at least 15,000 and it was determined that cross-breeding had extended from five to 59 centres in the seven-year period.

5. *National Field Station—"Gilruth Plains", Queensland.*—(i) *General.*—The summer rains of 1946 were light and there was a very limited response from the pastures. The period June to November was virtually rainless, but seven falls which aggregated 208 points in December gave a little relief. This response soon disappeared during January which was very hot and rainless, and by mid February full drought conditions prevailed once again. Complete and lasting relief was obtained by a series of falls amounting to 904 points in February. An isolated fall of 1½ inches was recorded in March. April was rainless, 84 points fell in May, and 141 points fell in June. The year therefore finished on a very sound note with pasturage assured for the first half of 1947-48. When it became evident that pasturage would be limited, firm measures were taken to reduce numbers of sheep carried so that young breeders only remained. When June, 1946 had passed without any winter rains falling, it was decided that the rams should not be joined with the ewes. Although there was thus no natural increase, the losses in the breeders through the drought period were exceptionally low.

Shearing was carried out in April with eleven months' growth of wool. The clip was very light but not badly affected with dust or seed. The cut per head of 7 lb. 11 oz. was 3½ lb. less than last year when the grown sheep yielded 11 lb. 3 oz. The wool sold fairly well at the May sales, the top price being 39½d. per lb.

From its inception in 1938 up to 1946, the research programme of the National Field Station had been chiefly concerned with studies relating to the blowfly problem. With the evolution of the modified Mules operation combined with the medium-long tail, as a means of blowfly control, it was believed that intense work on this problem was no longer necessary. The main experimental work on the animal side has therefore been designed toward investigations into methods of animal breeding. This change in programme has meant fairly extensive changes in the Field Station itself. The resident scientific staff has been increased, and additional station plant and facilities have been installed. There has also been expansion in investigations on pasture and plant problems during the year. Grazing trials which were interrupted by drought conditions were recommenced, and some attention has been given to fodder production and conservation.

(ii) *Salt Feeding Trial.*—To ascertain whether or not any beneficial effects could be measured when sheep were fed coarse salt, a small trial involving two groups each of 100 ewe weaners was commenced in June, 1946. One group had free access to coarse salt and a second group acted as a control. The groups were weighted fortnightly and at the same time they were changed from paddock to paddock. The trial was abandoned in December, 1946, when mortalities from general low nutrition in both groups were reaching high proportions. At no stage throughout the six months was there any evidence that the sheep receiving the salt were in any better condition than the controls. In any case, the rate of consumption of salt—less than 2 oz. per head per week—was too low to reflect any benefit even if this mineral was required.

(iii) *Animal Breeding Projects.*—With the ultimate object of contrasting various recognized systems of animal breeding, comprehensive long-term experiments were designed. The commencement of these trials was dependent upon provision of facilities in the way of extensive yards suitable for joining small groups of ewes with rams, and also on a satisfactory break in the drought conditions which prevailed during 1946.

(*a*) *Compensatory breeding trial.*—This trial was designed mainly as a guide in husbandry technique for the main experiment. It was also used as a spot trial into the mating of like with unlike to determine how far it may be possible to breed out undesirable features by reciprocal mating. Three groups, each of twenty ewes were selected for short dense wool, long open wool, and mossy face, respectively. These were mated, each group with one ram of an opposite type. The rams were run with the ewes for eight weeks commencing 23rd September. It is interesting to note that at this time of the year during the first seventeen days, only three services were effected and that only ten ewes, or 16 per cent., came on heat in the first 34 days. This occurrence of oestrus can be contrasted with the record of services in the main breeding trial in which mating started on 20th May and in which 95 per cent. came on heat during the first seventeen days.

Although the ewes in this small trial were with the rams for eight weeks, only 40 of the 60 were served, 25 lambs were dropped, and 24 of these survived. At a later date these lambs will be scored for the features upon which the ewes were selected, and the effectiveness of breeding out these features will be assessed.

(*b*) *Main breeding trial—Project I.*—The broad objects of this investigation are to contrast three systems of animal breeding. The trial is a complex one of long-term nature. The systems of breeding being contrasted are, first, the present method of breeding Merino rams in Australia—described as the Australian Mass Selection System (A.M.S.), second, the Hagedoorn Nucleus System in which a nucleus of homozygous sires is established, and third, the Family System as evolved by the Bureau of Animal Industry of the United States Department of Agriculture.

The well known weakness of a mass selection system of breeding is that animals are heterozygous for important factors and these are indistinguishable from animals which are homozygous. The Hagedoorn System aims at the establishment of a nucleus of sires which are proven to be homozygous for selected characteristics. The family system has a rather different approach to the same objective. Inbreeding follows as may; some families will collapse whereas with others, a highly productive line will be evolved in which homozygosity will be featured.

The sheep for this trial were selected in February, 1947, when 1,480 ewes were obtained by classing down a composite flock of 2,400, made up of the 1942, 1943, and 1944 drop station breeders. In all, 33 groups were established and mating commenced on 20th May, 1946.

(*c*) *Grazing trial and plant studies.*—The results of these studies carried out at the station are reported as from the Division of Plant Industry.

6. *Other Activities.*—(i) *Fleece Analysis Laboratory.*—(*a*) *Routine measurements.*—Equipment and accommodation have been obtained, and a nucleus staff trained, for carrying out routine measurements of the characters of fleeces required in experimental and other scientific work. During the year the following routine measurements were made:—Scouring tests—3,977, diameter distribution—4,873, mean diameter—571, density of fibre population—1,922, and staple length and crimp—5,353. Fleece samples measured came from experiments on the effects of nutrition on wool production, progeny testing, a survey of Merino wool production, and other observations.

(*b*) *Investigational work.*—Attention has been given to finding improved techniques for determining the total number of fibres in a bundle. A new method with greater accuracy and versatility than older methods was developed. In this, fibres are sectioned while under compression, the ends are ground and polished, and casts are taken in plastic of the cross section. The number of fibres is determined by counting the number of impressions.

(*c*) *Sampling for density measurements.*—Co-operative work has led to the development of a quicker and more accurate method of collecting samples used to measure the density of fibre populations. In this method the skin is subjected to tensions in two directions at right angles when measuring the area of skin from which the fibres were collected.

(*d*) *Length analysis.*—A dissection has been made of 25 samples of wool of all counts from 36's to 70's and it has been found that, contrary to widely held views, there are few fleeces of reasonably uniform growth in which 90 per cent. of the fibres are not at least as long as the staple length of the wool.

(*e*) *Significance of hairiness in Merino lambs.*—Three hundred samples were collected for the examination of the hypothesis that different degrees of hairiness in lambs were indicative of varying rates of approach to maturity and of differences in the fleece of the mature sheep. No evidence in support of this hypothesis was found.

(ii) *Investigation of Beef Production in Australia.*—Field work in connexion with the survey of beef production in Australia mentioned in the previous report, commenced in September, 1946. To date the surveys of the industry in Victoria and Tasmania have been completed and the Queensland section of the project was commenced early in June, 1947, with an examination of the coastal fattening districts. The information

obtained so far reveals a relatively precarious position of the industry in southern Australia. Current settlement policies are unfavorable to a continuation of beef production on many historic cattle properties. It seems, therefore, that the Australian market in the near future will depend to an even greater extent on carcass beef from Queensland. It is expected that the Queensland and New South Wales sections of the survey will be completed in the coming year.

(iii) *Poultry Breeding Investigations.*—The poultry breeding research unit has been established on portion of the Council's field station at Werribee, Victoria. It was decided that the first project should be a comparison of the following breeding systems:—(*a*) Phenotypic mass selection (White Leghorns). (*b*) Progeny test breeding (White Leghorns), including (1) the superior sire method (Hagedoorn Nucleus System), (2) the system of inbred sires with later cross-breeding between these lines, and (3) the Mount Hope Family Method. (*c*) Cross-breeding (White Leghorns x Australorps).

The results of these investigations will be of value not only in the poultry industry but also in connexion with other animals which reproduce and mature more slowly and to which similar systems of breeding will probably be applied in the near future.

The foundation stock of 450 White Leghorns and 50 Australorps was obtained at six weeks of age in October-November, 1946. Rearing was completed from colony houses on free range, and the pullets entered the laying pens in February-March. They are housed in groups of 50 and individual production records are obtained by trapnesting. Mating of individual hens with selected cockerels will be arranged by means of artificial insemination using the technique of Burrows and Quin.

7. *Publications.*—The following papers were published during the year:—

Dick, A. T., and Bingley, J. B. (1946).—Molybdenum-thiocyanate complex. *Nature* 158: 516-7.

Franklin, M. C. (1946).—Some nutritional observations on the drought feeding of sheep. *Aust. Vet. J.* 22: 104-12.

Gordon, H. McL., and Turner, Helen N. (1946).—Grazing management: continuous and rotational grazing of Merino sheep. 2.—Effect of continuous and rotational grazing on the infestation of sheep with internal parasites. Coun. Sci. Ind. Res, (Aust.), Bull. 201.

Graham, N. P. H., and Johnstone, I. L. (1947).—Studies on fly strike in Merino sheep. 8.—A surgical operation for the control of tail strike. *Aust. Vet. J.* 23: 59-65.

Graham, N. P. H., Johnstone, I. L., and Riches, J. H. (1947).—Studies on fly strike in Merino sheep. 7.—The effect of tail length on susceptibility to fly strike in ewes. Ibid. 23: 31-7.

Hill, J. L. (1946).—Factors influencing the distribution of arsenic over the fleece of sheep after immersion in arsenical solutions. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 245-50.

—— (1946).—The percutaneous absorption of arsenic by sheep dipped in arsenical solutions. Ibid. 19: 251-5.

Kelley, R. B. (1946).—Studies in the breeding performance of ewes. Coun. Sci. Ind. Res. (Aust.), Bull. 205.

Murnane, D. (1946).—Clinical bovine mastitis, its treatment and control. *Aust. Vet. J.* 22: 156-68.

—— (1947).—Third report on the treatment of infections of the bovine udder with penicillin: treatment of persistent subclinical and of quiescent chronic *Str. agalactiae* infections, and of clinical staphylococcal infections. Ibid. 23: 15-8.

Rogers, W. P. (1946).—Scientific method in the evolution of new drugs. XIV.—Comparative biochemistry and the selection of possible pharmacologically active compounds. *Aust. J. Sci.* 9: 55-9.

—— (1947).—Histological distribution of alkaline phosphates in helminth parasites. *Nature* 159: 374-5.

Reid, R. L., Franklin, M. C, and Hallsworth, E. G.* (1947).—The utilization of phytate phosphorus by sheep. *Aust. Vet. J.* 23: 136-40.

Reid, R. L., and Martin, N. D.† (1946).—The distribution of fluorine in potable waters in New South Wales and Tasmania. *Med. J. Aust.* II: 121-5.

* Agricultural Faculty, University of Sydney.
† Dental Faculty, University of Sydney.

V. BIOCHEMISTRY AND GENERAL NUTRITION.

1. *General.*—During the period under review, research in the more fundamental spheres of the nutritional physiology of sheep which, of necessity, had in part been set aside during the war, has gained momentum. The relatively slower development in the applied sphere is simply explained by the difficulties experienced in obtaining the materials necessary for fencing the areas and for watering the experimental flocks. The application of a considerable volume of findings ready to be translated into station practice is held back on this account. If the products of research are to flow naturally to application in the pastoral industry, it will be necessary to ensure an allotment of the really small quantities of materials which are required for experimental work in the field.

The course of construction of the new laboratory for the Division in the grounds of the University of Adelaide has made steady but slow progress. During the year the experimental bays in East Adelaide have been practically completed. The latter building will be used to accommodate the metabolism cages and other apparatus for experimental studies in nutrition and wool production. Within the next three years it is proposed to erect there a calorimeter for the direct estimation of energy dissipation by the sheep. This instrument will supplement the two indirect calorimeters which are in constant use at the laboratory.

The property at O'Halloran Hill has now been transferred from the Department of the Army to the Council. It consists of 600 acres of good grazing land situated south of Adelaide about 10 miles from the main laboratory of the Division. At this juncture the equipment necessary to render it a useful tool for nutritional research is being assembled there. A start has been made to sow two-thirds of the area with permanent pastures which will be used to support the Division's type-Merino flocks from which experimental animals are drawn; the other third will be used to produce special fodders necessary for experimental work. Arrangements are being made to build 50 pens at this site for experiments concerned with the problems of the nutrition of sheep. It is proposed to refer in future to this station as "Glenthorne", which was the original name of the property.

2. *Nutrition and Wool Production.*—It has been mentioned in previous reports that fodder proteins are the main source of the amino acids from which wool fleece is elaborated by the sheep under natural grazing

conditions, and that the capacity of the pastures to provide these raw materials usually falls short of the requirements for an optimum rate of wool production by high-producing Merino sheep. The limitations imposed by natural pastures, however, do not end there. Experimental studies have proven unequivocally that grazing sheep rarely, if ever, express their full hereditary wool-producing propensity, because the pastures of the greater part of the natural grazing lands of Australia are unable to provide the full complement of nutritive substances necessary for optimum growth and development of the lamb. In many areas where the nutritional quality of the fodder falls very short of the ideal, the conformation and size of the adult sheep is modified, and their capacity to produce wool is seriously impaired.

These limitations may be overcome by pasture improvement, but the nature of the wool will certainly change with the increased nutritional level which will follow. Depending on the market requirements, it may thus become necessary in the future to select strains which will produce efficiently relatively fine fleece when depastured on rich pastures.

It is important at this juncture to assess the relative efficiency with which various Merino strains deal with the pastures of the widely different nutritional levels representative of the main grazing areas in Australia. Experiments to this end will be started when the necessary materials are available.

In a series of experiments which have extended over several years, quantitative estimates at bi-monthly intervals have been made of the rate at which wool is produced by individual sheep of flocks depastured on a number of areas characteristic of the natural grazing conditions of South Australia and western Queensland. The findings indicated that during the course of any one year the normal variation in the nutritive quality of the pastures with seasonal change is sufficient to alter very perceptibly the rate of wool production. On some areas this rate varies over wide limits and in the course of a year may alter as much as 250 per cent. This change in rate of wool production is reflected mainly in change in the diameter of the fibres.

If those types of wool in which coarse hairy fibres abound are excluded, the expression "evenness of fleece" lacks precise meaning for the extent of variation of fibre diameters along the staple due to changes in nutritional level of the pastures may at times exceed the variation between different fibres at any fixed level of nutrition, which latter is an hereditary characteristic of the individual sheep. Translated into terms of spinning performance, the expression seems to be of no great importance.

The findings from experimental investigations proceeding in the Division have already shown that, if a maximum evenness of fibre diameters is to be attained, it would be necessary to provide throughout the year an evenness in the quality of fodder which would not be feasible under natural grazing conditions in most parts of Australia.

As the nutritional factors involved in wool production become clarified, the lack of precise technological definition of the dimensional characteristics of wool which are most desirable for manufacturing performance is further emphasized. Without this knowledge, the formulation of a long-term policy of wool production in Australia and of a programme of research upon which this will in part depend, will continue to be seriously handicapped.

3. *The Supply of Raw Materials for Wool Production.*—About fifteen years ago experiments conducted in this laboratory demonstrated unequivocally that limitations imposed on grazing sheep by the relatively small quantity of protein available from the natural pastures may in part be overcome if a supplement of protein is provided to the flocks, and that the response in greater wool production is such as to render the procedure economically feasible with wool at 16d. per lb. and the cost of the protein supplement less than £20 per ton. Under these circumstances the provision of between 1 oz. and 2 oz. of protein per day ensures that the value of the extra wool produced more than pays for the costs of the supplement and its distribution-

Wide-scale application of supplementary feeding has been limited by the supply of suitable protein concentrates, which has rarely been sufficient to meet the demands of animal industry for other purposes. The possibility of producing protein through the growth of micro-organisms *in vitro* was investigated; it is clear that the costs would render protein from these sources uneconomic for supplementary feeding.

In the past, attempts to convert simple nitrogenous compounds to protein through the agency of micro-organisms within the rumen of the animal itself have met with variable success. Knowledge of the factors which favour synthesis has been extended by the study of the nutritional requirements of the organisms which inhabit the paunch. Under normal conditions of feeding, the bacteria responsible for the fermentation of cellulose and of the other refractory carbohydrates of natural fodder are not as a rule limited by the available nitrogen. The opposite is true when starch and other easily fermentable carbohydrates constitute part of the rations. The population of micro-organisms which develops under these conditions very definitely responds to additions of simple nitrogenous compounds, and under certain conditions proliferates sufficiently rapidly to convert a large proportion of the added nitrogen to bacterial protein.

Experiments to determine the overall effects on wool production which supervene when urea is added to fodder similar to that available under dry-feeding conditions revealed that when this diet was supplemented with 15 g. urea per day the rate of wool production was unchanged. When the same quantity of urea was superimposed on a diet containing more readily available carbohydrate (starch from wheat) an increase of 30 per cent. in wool production resulted. This was approximately half the increase observed when the same diet was supplemented with the equivalent amount of nitrogen in the form of gluten—a protein of good quality. When starch was present there is little doubt that the greater proportion of the urea was converted to bacterial protein in the rumen, and that this protein was digested and absorbed at lower levels of the intestinal tract and was well utilized by the sheep.

These results suggest that urea, which may be manufactured in unlimited quantities, may find application as a protein substitute. Further experimental work is necessary before the economic feasibility may be assessed and final recommendations may be made for the use of urea as a supplement for wool production. Experiments have been designed to determine the minimum quantity of starch and of inorganic adjuvants which will need to accompany the urea if it is to be utilized economically by the sheep. These will begin within a month or so with animals in pens. Final tests under field conditions will be designed when this information is available.

4. *Metabolic Studies.*—(i) *Processes of Rumination.* —(*a*) *Utilization of urea.*—During the year certain aspects of the nutrition of micro-organisms which inhabit the rumen have been studied further, and this work is being continued.

(*b*) *Cellulose digestion.*—A series of experiments which have now been completed have shown that, under environmental conditions similar to those in the normal rumen, cellulose when fermented *in vitro* by associative growths of micro-organisms separated from actively fermenting rumen contents yielded acetic acid, propionic acid, carbon dioxide, and methane, together with

small quantities of butyric acid. These fatty acids constitute the main source of energy for the ruminant. Propionic acid very definitely predominated over acetic acid in the fermentation products. The carbon and energy balance sheets of the fermentations indicated that between 7 and 16 per cent. of the energy of the digested cellulose was transferred to micro-organisms and that the extent of proliferation of these organisms was determined by the duration of the fermentation. The free energy of the dissimilation of cellulose under these conditions was approximately 5 per cent. of the combustible energy, and most of this was liberated as heat in the exothermic reactions involved.

From these studies it may be concluded that the dissimilation products would provide to the animal between 85 and 86 per cent. of the combustible energy of the cellulose. If acetic acid enters without loss into productive channels of metabolism, all this energy would be useful to the animal; if acetic acid is rapidly oxidized and the heat wastefully dissipated, the useful energy of the products would be between 67 and 72 per cent. of the combustible energy of the cellulose. The fate of these fatty acids during their oxidation in the animal is at present under experimental investigation.

(*c*) *Absorption from the rumen.*—Physiological studies of the absorption of fatty acids from the rumen have been continued. A technique which employs either pectin or colloidal silica as an inert marker has been developed and by its use the relative rates at which the lower homologues of the fatty acids pass through the rumen wall have been determined. From acid solutions the rates were found to vary in the series butyric acid, propionic acid, acetic acid. Propionic acid was observed to be very much more rapidly absorbed under such conditions than acetic acid, and so the ratio of propionic acid to acetic acid in the rumen contents is usually much lower than unity. These differential absorption rates have thus proven misleading when attempts have been made by analysts of rumen contents to assess the relative proportions of fatty acids produced by fermentation in the paunch.

Under neutral or slightly alkaline conditions the fatty acids appear not to be absorbed from the rumen.

(*d*) *Intermediary metabolism of fatty acids.*—Experiments to determine the overall capacity of acetic acid and propionic acid to provide useful energy to the sheep have been continued.

These have taken two main lines—the study of the effect on the energy dissipation of fasting sheep following the administration of solutions containing either the free or the partially neutralized acids, and the study of the heat increment in the metabolism of sheep when neutral salts of these acids are superimposed on a maintenance diet. The results of these investigations will be reported elsewhere. Acetic acid, either free or in a partially neutralized condition, is not well tolerated by the fasting sheep. Physiological and biochemical studies have been undertaken to investigate the mechanism involved in the fatal consequences of passing dilute aqueous solutions containing the equivalent of 100 g. of acetic acid into the rumen of sheep which have been previously fasted for four or more days. Propionic acid in molecularly equivalent amounts is well tolerated under these conditions.

Further knowledge of the course of degradation and utilization of the simple fatty acids which arise from rumen fermentation is necessary if the energy metabolism of the ruminant is to be understood. Work along these lines is being actively pursued.

(ii) *Energy Metabolism.*—Studies on the energy metabolism of the sheep have been continued. During the year a series of experiments was started to investigate further the influence of protein on the energy dissipation of Merino sheep. This aspect is an integral part of a comprehensive study of the general problem of nutrition and wool production.

Since 1938 a considerable number of experiments have been conducted in this laboratory to determine the complete balance sheets of the energy transactions of sheep which have been fed on rations of widely different feeding values. In one series, five different fodders were fed in 25 different proportions to groups of five animals, so that the separate effects which the fodders, the state of energy balance, and the size of the animal exert on the energy dissipation might be assessed. The results have been analysed mathematically, and estimates have been made of the separate effects of these factors. They have been found to be additive and substantially independent. The heat increments brought about by different fodders have been shown to depend on the amount of energy in the protein and non-protein components of the rations that are catabolized, and on the amount of energy in the methane evolved and in the faeces excreted. After the values of these parameters had been assessed, the correlation between observed and computed energy dissipation was found to be +0.95. Application of the same method of computation to a further 22 diets of other types examined in this laboratory, and to a number of balances on cattle determined in laboratories in the United States of America, resulted in a similar high degree of correlation between the observed and the computed metabolic rate. As the feeding value of a fodder depends on the difference between the available energy (the combustible energy of the food minus that of the excreta) and the heat increment (the increase in energy dissipation of the animal), this work will provide a basis for a better estimation of feeding values than has hitherto been available.

5. *Vitamin A Requirements of the Sheep.*—The investigations which are in progress to determine the nutritional disabilities imposed on the sheep by vitamin A deficiency under Australian grazing conditions have been outlined in previous reports. During the period under review the results of some of these investigations have been published; they have provided the background of knowledge essential for the assessment of the extent of vitamin A deficiency in the sheep. The effects of low carotene intake on reproduction which are now being studied with groups of experimental animals confined in pens were mentioned in the 1945-46 report. The experiment has been continued throughout this year, and the results of further deprival of vitamin A will be observed.

6. *Physiological and Tissue Metabolism Studies.*—(i) *Tissue Respiration.*—The effect of potassium cyanide on the cytochrome system *in vitro* was investigated further. Variations in the concentrations both of cytochrome oxidase and of cytochrome c were observed to alter the degree of inhibition at a fixed cyanide concentration. It would thus appear that this is due either to a competitive effect between the cyanide and the cytochrome c or to the removal of some of the cyanide from the sphere of action by combination with the protein moiety of the cytochrome c. Further experiments are in progress to investigate the mechanism of the action of cyanide on oxygen transfer in tissues. This work is an integral part of the study of the functions of minor elements.

(ii) *Cobalt and Arginase.*—In preliminary experiments the activating effect of cobalt on the enzyme arginase has been confirmed. A study of the urea cycle in cobalt-deficient animals will be undertaken when suitable experimental material becomes available.

(iii) *Fat and Carbohydrate Metabolism.*—Work on the intermediary metabolism of fats and carbohydrates in the sheep has been continued. Certain aspects of the metabolism of the lower fatty acids have been investigated in phlorhidinized sheep. Under some conditions

the administration of acetate to phlorhidinized sheep leads to a definite increase in the excretion of glucose in the urine. The response seems to vary with the nutritional state of the animal.

(iv) *Operative Technique.*—The technique for establishing fistulae in the abomasum of sheep has been perfected. Animals with permanent fistulae established by this means in the abomasum will survive indefinitely and behave normally. The approach to many biochemical and physiological problems concerning the ruminant will be greatly simplified by the use of these animals.

7. *Chronic Fluorosis.*—The reasons for extension of experimental work on chronic fluorosis in the sheep have been outlined in previous reports. The experiments to determine the long-term effects of ingestion of water containing fluorine in concentrations similar to those which are present in the waters from bores which tap certain of the artesian basins in Australia have now been in progress for approximately two years. The second pair of incisor teeth erupted by some of the animals on water containing 2.5 parts of fluorine per million show signs of mottled enamel which is a characteristic symptom of chronic fluorosis. These lesions have been more serious in the incisors of the sheep which have received higher concentrations of fluorine, and the incidence and extent of the mottling is closely correlated with the fluorine concentration up to twenty parts of fluorine per million in the water which was the highest level investigated. All the experimental sheep, however, have remained healthy and their wool production has been normal over the first two years of the experiment. As yet the dental lesions have not had any adverse effect. The experiment is being continued.

8. *Minor Elements.*—The general findings of the experiments concerned with minor element deficiencies were discussed in the 1945-46 report. The experiments mentioned there have been extended and new ones have been undertaken. It has been proven that the wool is first to suffer when the sheep's copper status is reduced. The mechanism concerned with the normal process of keratinization quite obviously demands a relatively high concentration of copper. When this falls, oxidative closure of the thiol (-SH) groups of the prekeratin to the disulphide groups (-S-S-) of keratin is materially delayed, and the wool fibre is extruded from the follicle in a semi-plastic state to oxidize slowly in air. The growth of straight, characterless, lustrous wool which results is the first symptom to appear. It is a specific, sensitive, and readily discernible sign and so is an ideal indicator of copper deficiency. By taking this lesion as a first criterion, the copper-deficient areas of southern Australia have been mapped, and copper-deficient areas have been recognized on hitherto unsuspected country in Queensland, Tasmania, and Victoria.

The profound overall effect that copper deficiency exerts on the wool fleece has been reported previously. Data of an experiment designed primarily to investigate the overall effects of copper supplements on the wool grown by sheep while depastured on terrain which is frankly copper-deficient, indicate the economic returns that might be expected from the provision of copper supplements to sheep grazed on areas of different degrees of copper deficiency. The wool production and value of the fleece of a group sheared in 1946 and receiving no supplement of copper was 4.3 lb. and 105 pence as compared with 7.8 lb. and 215 pence for a group receiving 20 mg. of copper per day. Groups receiving smaller amounts of copper gave intermediate results.

The grazing conditions of the 1946 season were better than those of 1945. This is reflected in the heavier fleeces grown by those animals which received an ample supplement of copper. The unsupplemented controls were unable to benefit from the better fodder.

(i) *Field Stations.*—(*a*) *Robe.*—(1) *The effects of various degrees of copper deficiency on wool production by Merino sheep.*—A summary of the overall findings from this experiment is discussed above. After the second shearing all these ewes were mated and, on lambing, intensive chemical, histopathological, and haematological studies were made on the lambs and on their dams. The analyses involved are at present being carried out. The results will allow the effects which various stages of copper deficiency exert on reproduction in the sheep to be clearly defined.

(2) *Grazing trial on copper-dressed pastures.*—The results of this trial have been reported previously. All ewe progeny from the original ewes have continued to graze on pastures which were top-dressed with copper in 1940. It is already evident that these pastures are unable to provide the full complement of copper needed by the sheep. The wool of those which have received no additional copper tends to show some signs of the copper-deficient lesion. However, their lambs have been healthy and none have developed ataxia. The first generation of ewes will produce their fourth successive lamb this year and the second generation ewes will also lamb. This trial will proceed for some years further.

(3) *Cobalt deficiency of pastures.*—Sheep have now been grazed for over a year on paddocks of the deficient littoral at Robe which have been top-dressed with 1 lb. of cobalt sulphate per acre. Those which have had no additional cobalt are now suffering from obvious signs of incipient cobalt deficiency. One of the lambs of these ewes developed the symptons of acute cobalt deficiency. The ewes have again been mated and the observations will be continued.

(4) *Black wool and copper deficiency.*—The relationship between copper and pigmentation in normally black-woolled sheep is now well established. The wool of black sheep becomes progressively less pigmented as their copper status is lowered. On dosing with copper, pigmentation in the newly grown wool is restored immediately, along with the natural crimp. Further experiments are being carried out to determine whether the failure of the pigmentation is an earlier manifestation of copper deficiency than the loss of crimp.

(5) *Cobalt deficiency.*—Experimental evidence which proves unequivocally that massive doses of dried liver have no beneficial effect on sheep depastured on cobalt-deficient country has now been completed. When these animals had developed the unmistakable signs of cobalt deficiency, oral supplements of cobalt invariably reinstated them to normal health. Depot therapy with active liver extracts was likewise without effect either in preventing the onset of cobalt-deficient symptoms or in bringing about any improvement in the anaemia.

Experimental animals for intensive work in the laboratory will be drawn from a group of young ewes which have been transferred to the cobalt-deficient terrain.

(6) *Estimation of the rates of storage and of depletion of copper.*—The liver biopsy technique developed by colleagues in the Division of Animal Health and Production is being applied to determine the rates of storage and of depletion of copper and iron in the livers of sheep on normal and deficient pastures.

(7) *The mode of action of cobalt.*—An experiment is being conducted to determine whether cobalt administered direct into the abomasum of sheep is as effective in preventing cobalt deficiency as cobalt administered *per os.* The latter finds its way first to the rumen. The fact that cobalt administered directly into the blood stream exerts no beneficial effect was proved here some years ago.

(*b*) *Field Stations other than Robe.*—(1) *Keith: Copper-dressed pasture trials.*—The results of experimental observations of sheep depastured on the copper-deficient siliceous sands at Keith (South Australia), have indicated that the initial dressing of 7 lb. CuSO4 per acre applied in 1943 is no longer sufficient to provide the full copper requirements for normal wool production. This trial has been interrupted to permit re-establishment of the pastures of the experimental areas. No further application of copper will be made, and observations will be continued with other groups of sheep when the pastures are ready for grazing.

(2) *Borrika: Copper-dressed grazing trial.*—This area has had an extraordinarily good season, with the result that the best wool ever produced on this property was grown by the flocks on the copper-dressed pastures. No difference was observed in the ewes of this flock which were provided with additional copper as a supplement.

(3) *Glenroy.*—Experimental trials in this area have proved unequivocally that, in certain seasons, the pastures there are cobalt-deficient. Comparison of the growth rates of lambs on areas top-dressed with cobalt sulphate with those on adjacent untreated areas revealed no difference during the past year. This type of terrain is characteristic of incipiently deficient areas where the effects of cobalt deficiency are on occasions acute while at other times no signs of deficiency can be detected. The behaviour of the young sheep is being used to indicate the periods when deficiency occurs. The conditions which lead to this occasional state of deficiency will then be investigated.

(4) *Kybolite.*—The trial undertaken at Kybolite in co-operation with the South Australian Department of Agriculture has indicated as yet no evidence of copper or cobalt deficiency.

(ii) *Queensland.*—A report on the experiments which proved the existence of copper deficiency in certain areas of Queensland has been prepared and presented for publication.

(iii) *Fleeces from Experimental Sheep.*—Sets of fleeces from the experimental groups of sheep in which the effects of varying degrees of copper deficiency are apparent have been presented to State Departments of Agriculture in Australia for use in extension and educational work. A report on minor element deficiencies suitable for extension workers has been requested by the South Australian Department of Agriculture. This is in the course of preparation. It will be issued as an information circular and will serve to bring up to date the information previously supplied in this way.

(iv) *Physiological Function of Trace Elements.*—Experimental work has been undertaken to illuminate further the physiological function of the trace elements copper, zinc, and cobalt. Radioactive isotopes of zinc and of copper are being employed as markers in this work. The findings will be discussed in later reports.

9. *Agrostology and Plant Nutrition.*—The investigations of the nutritional factors which limit the growth of cereal and fodder crops on the calcareous littoral of South Australia have been referred to in previous reports. These areas support in their natural state a very limited plant association in which the two indigenous grasses *Lagurus ovatus* and *Bromus madritensis* overwhelmingly predominate. Whereas rye corn did well on these deficient tracts, other cereal crops failed completely, and all attempts to establish sown pastures by ordinary methods had proven invariably to be unsuccessful. Experimental investigations with sheep on these areas disclosed serious copper deficiency. This provided the first clue which led to the striking experimental demonstration that cereal and fodder crops could flourish there, providing copper was applied in relatively small concentrations (at the rate of approximately 7 lb. $CuSO_4.5H_2O$ per acre) and it was found that for some plant species additions of zinc were also necessary. Over 2,000 square miles of the seaboard in the relatively high and secure rainfall zone of South Australia are limited in this way. In the hinterland, the soils of the vast mallee "deserts" were proved to be copper-deficient by employing, as a first criterion, the lesion in the wool of sheep grazing on the sparse cover. During the past three years, investigations carried out on the singularly deficient Laffer Sands, which are characteristic of the worst areas of the "deserts", have revealed that these very much greater areas are similarly limited by very small quantities of minor elements available from the soils.

Pasture Production on the Laffer Sands in the Region of Keith, South Australia.—The phosphate status of the Laffer sand is extremely low, and the growth of all plants is negligible unless phosphate is applied. Even with the addition of phosphate, subterranean clover does not persist and the growth of lucerne is very sparse. Experiments have proved that additions of zinc increase very materially the growth of subterranean clover. While the addition of copper had no effect on its vegetative growth, both copper and zinc were indispensable for satisfactory seed production, and so for the persistence of this plant. As additional copper was essential for seed production but not to the same degree for vegetative development, the effect of copper was not easily detectable in the first year. Subterranean clover which had received a dressing of both zinc and copper grew extremely well, and the population of plants increased each year. With the omission of either, the plants were unable to reproduce the sparse population of the seeding year. Very heavy dressings of superphosphate at seeding (4 cwt. to 8 cwt. per acre) were much less beneficial than lighter dressings (1 cwt. per acre). The seedlings which developed after late summer rains in the early months of 1946 developed a marginal, and then complete, necrosis of the older leaves. Pot culture experiments suggested that this lesion was associated with nitrogen deficiency: healthy plants could be grown in pots under the same conditions by addition of either nitrate of soda or of lime, but not by the addition of a number of trace elements including molybdenum. This phenomenon is being investigated further. However, the plants from the next germination which supervened in the field after the autumn rains developed normally and grew vigorously.

The behaviour of lucerne grown on these soils differed from that of subterranean clover in response to manurial treatments. Copper stimulated the vegetative growth and zinc did not, and growth of lucerne on new land was augmented by additions of increasingly heavy dressings of superphosphate up to levels of 8 cwt. per acre applied at seeding. The response to the addition of copper increased with the quantity of phosphate dressing.

The introduction of leguminous plants into the sandy heath soils of the Ninety-Mile Desert and their maintenance in a vigorous condition will enable a system of farming to be adopted which will lead to a very great improvement in soil fertility. The current system of farming in the better parts of this deficient terrain, of necessity, leads all too rapidly to soil impoverishment.

While there is yet much experimental work to be done before all the limiting factors are revealed in these deficient soils, it is already clear that a new era in their development is indicated, and that millions of acres of land which have been abandoned as worthless for agriculture will be brought into useful bearing.

10. *Accessory Food Factors and Food Composition.*—During the year the investigation of the methods for determining thiamine in cereals and in bread has

been continued. The method commonly used for determining thiamine in bread is far from satisfactory and means for overcoming one of the most serious defects have been developed.

A review on the influence of the milling process upon the nutritional value of wheaten flour and bread has been written and will shortly be published.

11. *Publications.*—In the period under review a number of papers and monographs on various aspects of the work proceeding in the Division have been prepared and submitted to various scientific journals for publication. At this period there is a considerable delay in publishing. A record of these will be provided in future reports. The following papers were published during the year:—

Marston, H. R. (1946).—Nutrition and wool production. Proc. Symposium on Fibrous Proteins, Leeds.

Peirce, A. W. (1946).—Changes in the concentrations of carotene and of vitamin A in the blood of sheep grazing on natural pastures in South Australia. *Aust. J. Exp. Biol.* 24: 231-40.

—— (1947).—Changes in the concentrations of carotene and of vitamin A in the blood and liver of lambs with increase in age, and in the colostrum of ewes. *Ibid.* 25: 111-7.

VI. SOILS INVESTIGATIONS.

1. *General.*—The year under review completes the twentieth year of soil surveys by the Council in Australia. These surveys began in 1927 as a result of the needs of the Irrigation Settlements of the Murrumbidgee Areas and in the Murray Valley for a detailed knowledge of the soil types under exploitation, their distribution, and their chemical and physical properties. On the basis of the knowledge so obtained it has proved possible to place the work of the research stations connected with irrigation on a sound footing so far as soils are concerned.

The surveys were later extended to deal with areas presenting problems of special importance in connexion with animal production, afforestation, erosion hazard, or closer settlement.

The major portion of the field and much of the laboratory activity during the past two or three years has been directed towards the study of areas intended for land settlement schemes for returned servicemen. The areas involved in Australia are too large for detailed work to be attempted by the Soils Division within the time available, and attention is therefore directed towards those areas in which a major change in land use is contemplated such as from dry farming to irrigation or from native vegetation to seeded pastures. The field operations of the Division are decentralized so far as possible, and regional centres have been established in Hobart, Perth, Deniliquin, and Canberra.

The Division has its head-quarters at the Waite Agricultural Research Institute of the University of Adelaide and the staff of both bodies are closely associated in research. Co-operation with State Departments of Agriculture, Lands, Forestry, and Irrigation is a necessary feature of the work of the Division, and in the Commonwealth sphere contacts have been maintained with the Ministry of Post-war Reconstruction and the Departments of the Interior and of Agriculture and Commerce.

2. *Soil Survey Section.*—Soil surveys have been carried out in all the States except Queensland, but part of that State is actually embraced in a current survey being carried out on the Barkly Tablelands under the auspices of the Northern Australia Development Committee.

A great deal of reconnaissance work, involving mapping on a broad scale or the evaluation of land types or the critical inspection of problem areas, has been carried out but cannot be assessed properly in terms of area. Surveys ultimately reach their final stage, detailed mapping, and in this way a gross area of 215,000 acres was covered last year.

It has been part of Divisional policy to maintain a small group on erosion investigations in association with a State conservation authority. So far this has operated in Victoria and South Australia, and in both States studies are in hand at present.

(i) *South Australia.*—The soil survey of the projected Loxton Irrigation Area has recently been completed. This survey of some 10,000 acres of mallee land adjacent to the south bank of the River Murray at Loxton is intended to assist the South Australian authorities in the design of a new horticultural settlement and has already been used in the initial subdivision plans and selection of portions for spray and furrow irrigation.

In the first part of 1946 a reconnaissance survey of the northern marginal lands was made at the request of the State authorities. In the latter part of 1946, the mapping of the soil and erosion data collected earlier was completed and a report prepared for the information of the Marginal Lands Committee and the Department of Agriculture, one of whose officers assisted with the field work. During the month of June, 1947, the detailed soil survey and investigation of erosion and land use in the four Hundreds of Willochra, Coonatto, Pinda, and Eurelia have commenced in co-operation with an officer of the Soil Conservation Branch of the Department of Agriculture.

Assistance was given to the Parliamentary Land Settlement Committee in its investigations of development on Kangaroo Island and in the Murray Valley. In February, 1947, an officer of the Division, after a preliminary reconnaissance of Dismal Swamp and adjacent lands in South Australia and Victoria, took part in an interstate conference at Mount Gambier concerning the possible drainage of the swamp lands into the Glenelg River in Victoria.

(ii) *Victoria.*—The compilation of the maps, the collation of the data, and the report on the soil survey and erosion investigation in the Dookie district, mentioned in last year's report, will shortly be ready for publication as a bulletin.

Soil surveys have been continued, both in Victoria and New South Wales; of properties affected by toxaemic jaundice in sheep. Soil maps and reports have been prepared for five properties and forwarded to the Division of Animal Health and Production. This work is part of a co-operative attack by the Soil Chemistry and Survey Sections in collaboration with other divisions of the Council.

During the year, soil sampling was completed on a number of properties in Victoria and New South Wales on which *Nicotiana rustica* had been grown on an experimental scale. A report on the morphology and chemical characteristics of the soils in relation to crop production has been prepared. Within the areas studied, crop husbandry and climatic features seem to be more important than soil characteristics.

In October, 1946, an inspection of the land slip and erosion problem of the Coleraine district was made in company with officers of the Soil Conservation Board and the Department of Agriculture. A soil survey and erosion investigation were decided upon, and in April, 1947, a commencement was made with this work. It was suspended for the winter period but will be resumed in late 1947, in weather more suitable for field work in that region.

Brief inspections have been made at Mildura and Red Cliffs of areas adjacent to the present irrigation settlements which were considered as possibly suitable

for development. Two areas were soil surveyed in detail for future settlement but only one of these proved suitable.

Along with officers of other State and Federal Departments, an inspection was recently made of three properties in the southern mallee area, to determine if possible whether such properties might be used for settlement of ex-servicemen. In the report on these properties, attention is drawn to the incidence of salinity and wind erosion and the necessity to take such phenomena into account in any plans for settlement.

(iii) *Tasmania.*—Soil survey work in Tasmania has been confined during 1946-47 to estates on which it is intended to settle ex-servicemen. These estates, which cover 70,000 acres, for the most part lie in the Derwent and tributary valleys and in that part of the Launceston Tertiary Basin known as the Northern Midlands. Detailed soil survey for settlement has also been done on areas of Crown Land on King Island, formerly covered by a reconnaissance survey in 1931.

Soil survey work on the Montagu and other north-western swamps was again prevented by climatic conditions and pressure of the work outlined above. This is a major project of very considerable difficulty both in conditions of field work and in the character of the problems presented. It is intended to carry this investigation to completion in the next favorable summer period.

(iv) *Western Australia.*—As a preliminary to soil association mapping over the extensive Great Southern Region which embraces a broad belt of land extending from Mount Barker to Williams, spot surveys have been carried out in seven localities to determine the soil type components of the soil associations. The area is continuous with the Rocky Gully area which was surveyed last year and represents an extension of soil survey work in Western Australia into moderate rainfall areas (22–25 inches). The region is of particular interest not only because of its soil characteristics but also because of the present high incidence of infertility diseases in sheep and because of projected land settlement of ex-servicemen. It is also an area in which salinity and associated erosion manifest themselves in a slight to moderate degree. The spot surveys which are located so as to assist not only in the study of the composition of the soil associations but also to be of direct value in land settlement, will also provide basic data for current infertility research and for any subsequent investigation of the salinity and erosion problem.

Over a wider area a number of inspections of the soils, particularly in relation to salinity and erosion, have been carried out at the request of the War Service Land Settlement authorities on estates on which settlement has been projected.

(v) *New South Wales.*—During the year the field work on the alluvial soils of the projected Abermusden Irrigation Area was completed and a commencement has recently been made on the survey of the soils of the associated valley sides and hills on which there is a significant incidence of erosion.

Following an earlier inspection of the soils of the Northern Rivers district where a declining fertility of pastures is causing concern, a soil survey and chemical unit accommodated in a mobile laboratory, has commenced work at Wollongbar. This survey, both in its field and laboratory aspects, is being done in conjunction with the Department of Agriculture and the Council's Division of Plant Industry.

As in past years extensive work has been done in the Riverina. A very detailed soil survey has been completed of the Council's Falkiner Memorial Field Station, and a commencement made with the detailed survey of the Deniboota Irrigation Area of which a reconnaissance survey was made several years ago. Both detailed and reconnaissance surveys as required have been made of twelve properties being submitted for settlement of ex-servicemen, and reports submitted to the New South Wales Closer Settlement Board and Commonwealth War Service Land Settlement authorities.

Regional reconnaissance is being steadily pursued and at one stage embraced an inspection of the soils of the lands associated with the lower course of the Murrumbidgee river. Information on the soils of the region is required in connexion with the possible use of Snowy river water to assist the decision as to its diversion to the Murrumbidgee or Murray rivers.

Recently a start has been made with a detailed soil survey of an area at Coomealla where a new irrigation settlement is proposed. The gross area to be surveyed is about 12,000 acres adjacent to the existing settlement.

(vi) *Northern Australia.*—Between June and October, 1946, a party which included an officer of this Division carried out a reconnaissance of the Darwin-Katherine region. This expedition working under severe field conditions produced the first scientific report embracing botanical, geological, soil and land-use characteristics of a wide area in the Northern Territory.

The area was divided into seventeen land types whose soil and vegetational character has been defined so that future examinations of any portion of the region may be based on sound scientific data.

A report for the Northern Australia Development Committee on the soils of the area has been prepared by the officer concerned, which, with the other information collected, leaves no doubt that, at best, there is only limited scope for agricultural development in the region. In May, 1947, a joint expedition with the same personnel commenced a similar appraisal of the Barkly Tableland. It is anticipated that this project will require field work extending over two seasons.

(vii) *Soil Surveys of Building Sites.*—Soil surveys and inspections of suburban areas in both Melbourne and Adelaide have been carried out with the object of assisting the work of the Section of Soil Physics and Mechanics and as a basis for modification of foundation structures in numerous housing projects being undertaken by the State authorities. It is hoped ultimately to classify the soils according to their engineering and building characteristics and prepare a map of the capital cities showing the location of such soil groups. Initially the survey is being largely concentrated in Adelaide.

3. *Soil Chemistry Section.*—During the year the routine analyses required by the Soil Survey Section have been carried out on an increasing number of samples. Attention is constantly being given to the improvement of techniques and adaptability of new methods to the needs of the surveys.

Studies on soils associated with toxaemic jaundice of sheep have been continued. An extensive pot experiment confirmed results obtained in the previous year that pasture plants growing on the soil from the Barooga Field Station did not have a higher copper status than the same species growing on Waite Institute soil. For both soils, the copper in the plants was of the same order as that noted as the normal range by Western Australian and New Zealand workers. The copper content was appreciably higher, however, than that of the same plants growing on a meadow podsol from Kybybolite. Both the Barooga and Waite Institute soils belong to the red-brown earth group.

The effect on the copper status of the plant of an alteration in the soil reaction (by the use of sulphur or lime) was also investigated. Increasing the acidity of the Waite Institute soil to about pH 4.7 tended to

increase the amount of copper taken up by the plants. The same increase in the acidity of the Barooga soil did not markedly affect the copper uptake.

Change of soil reaction produced marked effects on the uptake of molybdenum by all three plant species. As has been noted by others, acid conditions decreased the uptake and alkaline conditions favored high uptake. The application of molybdenum to the soil did not affect the yield or copper uptake of the plants in either soil type. There was, however, a big increase in the amount of molybdenum taken up from the molybdenum-treated soils. As before, the uptake was greatest from the alkaline soils.

A field survey of the reaction of the surface soil of the Barooga Field Station and an adjacent property has been carried out. This disclosed that the soils of the field station were distinctly more acid than those of the adjacent property. The significance of this is being further examined.

As indicated previously a soil fertility survey has been commenced at Wollongbar, New South Wales. In the preliminary survey, attention is being directed, on the chemical side, to reaction, lime requirement, and organic content of the soils. As the investigation proceeds, other determinations likely to assist in determining the cause of the decline in fertility of these soils will be investigated.

Methods of analysis have continued to receive attention. Methods for the determination of phosphates in soils have been investigated and a colorimetric method has been suitably adapted to yield accurate results, even in soils high in iron and low in phosphate.

Methods for the determination of molybdenum in plant materials have also been investigated and a new method developed. This method not only yields accurate results for quantities of molybdenum as little as 1-10 gamma, but it also enables the determination of copper and molybdenum in the same plant digest. The method is based on the preliminary extraction of molybdenum with cupferron and the production of a deep-green coloured complex with dithiol.

The arrival of the Hilger Medium Spectrograph has enabled further progress to be made with the acetylene flame method for the determination of exchangeable cations. The method is now in use for the routine determination of exchangeable cations in many soils. Some fundamental work remains to be done before the method can be adopted for all soils coming in from the various surveys. Other spectro-chemical technique has been investigated. A comprehensive study of the behaviour of soil, plant ash, and other samples of biological interest, in the direct current arc under different conditions, has been made in order to effect improvement in methods used for arcing these substances and so obtain results which are more strictly quantitative.

The spectrographic equipment has been used to assist in a number of investigations both within the Council and for other organizations. Various samples of subterranean clover, together with the soils on which they have been grown, have been examined from areas giving rise to infertility in sheep, but no positive clues of any mineral factor have so far been disclosed. In connexion with the toxaemic jaundice investigations, a number of liver samples have been examined for their less common mineral constituents; the plant samples from the pot experiment are also being examined similarly.

4. *Soil Physics and Mechanics.*—The main lines of investigation of this Section have continued to be in the fields of soil-water relations, soil structure and texture, and the engineering properties of soils.

(i) *Soil Texture.*—The increasing experience of the Division has made possible a revision of the triangular diagram conventionally used to express the relationship between the field description of texture of a soil and its mechanical composition. The first such diagram was published by the Division in 1934. A new type of texture diagram has also been developed in which the median size of the non-clay fraction is plotted against the clay content.

(ii) *Mechanical Analysis.*—A new plummet method has been developed for measuring the density of soil suspensions. This allows a more critical measure of density to be made than is obtained with soil hydrometers. The instrument is more sensitive and allows measurements to be made corresponding to a limiting settling velocity which can be more accurately defined. Readings of density can be obtained as rapidly as with an hydrometer.

(iii) *Soil Structure.*—An investigation into the effect of a wheat-fallow rotation on soil structure has been concluded. A significant decrease in water-stable aggregates was found. The major part of the decline which occurred over a period of up to twenty years took place in the first five years of cultivation. Cultivation was also found to have caused a significant decrease in the nitrogen content. From statistical evidence, it is improbable that, in the cases examined, the decline in nitrogen was itself the main immediate cause of the parallel decline in aggregation which resulted from cultivation.

Work is being continued in co-operation with the Council's Research Station at Griffith (New South Wales) on changes in structure occurring under various reconditioning treatments of old irrigated orchard land.

Statistical investigations have been carried out on the relation of mechanical composition and nitrogen content to water-stable aggregation. It has been found that, in the soils studied, clay and silt content are both positively related to aggregation but that there was no significant relation for nitrogen content.

A procedure has been developed for examining soil structure in relation to a descriptive system being evolved by the Soil Survey Section. The resistance offered to the subdivision of large aggregates into smaller units and the hardness and size of these units are being examined. From data so far available, it appears that the descriptive method can be represented quantitatively.

(iv) *X-ray Diffraction.*—An X-ray crystallograph has recently been obtained for studying the crystal structure of clays. The change in structure which takes place when water is adsorbed by clays is being investigated. This is being related to the phenomenon of swelling which is of importance in regard to the stability of house foundations. It is intended later to undertake a survey of clay minerals occurring in Australian soils.

(v) *Movement of Water in Soil.*—Work has been continued on the irrigation characteristics of soils of the new irrigation area at Loxton (South Australia). A number of the soil types studied earlier possessed highly calcareous subsoils, some of which were in the form of hardpan. The effect of pan upon water movement has been studied in more detail, and it has been concluded that it is unlikely to be a serious factor contributing to seepage trouble in the area.

Comparisons have been made between infiltration measurements by the ring infiltrometer and the spray infiltrometer recently developed by the Division. It has been shown that in the soils examined the guard area of wetter soil around the test plot of the spray infiltrometer restricts lateral movement sufficiently to make the results comparable to those which would be obtained if a large area were wetted by spray irrigation. On the other hand only 30 per cent. of water entering the same soils from a ring infiltrometer penetrates vertically. The lateral movement of 70 per cent. of

the water away from the test column results in excessively high values for the infiltration capacity when the ring method is used. The ring method is nevertheless of great value as a relative measure of infiltration.

(vi) *Retention of Water by Soils.*—The principles underlying water movement have been investigated further. Laboratory work has confirmed the low tensions recorded at field capacity in sandy soils last year under field conditions. Similarly the tensions noted during water application have also been confirmed. The scope of this investigation has been extended to cover tension measurements during applications of water and at field capacity in a loam and a clay soil. From work in progress it appears that tensions in these soils at field capacity will also be found to be much lower than the commonly accepted values. Transmission tensions (tensions recorded during application of water) were found to be of the same order as those recently reported overseas.

The measurement of water retention at low water content by means of the freezing point method was continued. It was found that the depression of freezing point of soil water at the permanent wilting percentage could be taken as corresponding to 1.5° C. The freezing point method is useful as an indirect method for determining the permanent wilting percentage.

(vii) *Electrical Measurements of Water Content and Temperature of Soil.*—Further work has been done on *in situ* methods for determining water content of soils indirectly. The electrical conductivity of gypsum blocks and a dielectric method have been examined. A number of field installations of gypsum blocks have been made in connexion with investigations on soils under house foundations.

In the course of this work it was found that soil temperature affected the results sufficiently to warrant a correction being applied. A new type of soil thermometer was developed for this purpose. Temperature was measured indirectly from the electrical resistance of a solution of sodium chloride contained in a small cylinder buried near the gypsum block. This thermometer possesses the advantage of requiring simpler measuring apparatus than is necessary for use with thermocouples. In the field, the same instruments can be used for measuring resistance of both gypsum blocks and thermometers.

(viii) *Soil in Relation to House Foundations.*—Investigations recently commenced by arrangement with the Building Materials Section on soil as a foundation material for houses have been continued. Soil maps have been prepared by the Soil Survey Section and the physical properties described for various suburban estates. The work has been undertaken to assist architects of the Housing Commission of Victoria and the Housing Trust of South Australia in their design of foundations which is varied according to the type of soil. General information is being built up on soils in the suburban areas at the same time.

An important part of this project is the study of moisture changes under houses and the soil movement resulting from this because of the shrinkage or swelling of the soil. Field installations of electrical moisture meters have been made. In the laboratory, swelling is being studied in relation to crystal lattice structure and by measuring volume changes of soil clods. The field moisture studies are co-ordinated at a Sydney site with studies of experimental foundations being made by the Building Experiment Station, Department of Works and Housing, which is working on the question of foundation design.

(ix) *Miscellaneous.*—The properties of soils have been examined in an area intended for testing the mud-crossing ability of Army vehicles. Soil has also been examined for its suitability for soil-cement construction in a suburban street.

5. *Soil Bacteriology.*—Investigations were continued on the possible influence of molybdenum on nitrogen fixation by *Rhizobium* in association with a leguminous plant. By using *Phaseolus lathyroides* with and without inoculation, as the host plant growing on a Tasmanian soil responsive to molybdenum, evidence was obtained that the molybdenum is effective only with inoculated plants and that similar responses can be obtained by the use of nitrogenous fertilizers in the absence of molybdenum. Investigations upon the growth of *Clostridium butyricum,* a non-symbiotic nitrogen-fixing organism occurring in certain soils under anaerobic conditions, were made with a view to ascertaining the role of molybdenum in nitrogen fixation under these conditions.

The demand by farmers for cultures of *Rhizobium* strains for the inoculation of legume seeds has increased considerably and during the past year some 1,500 cultures have been supplied, in comparison with 700 cultures for the preceding twelve-monthly period. All strains so distributed have been tested for their effectiveness under controlled conditions in the glasshouse. A large stock culture collection of other strains has also been maintained. Studies have been commenced upon the life, growth, longevity, and death of species of *Rhizobium* in liquid cultures under varying conditions of aeration, and upon the resistance of such organisms to desiccation and lyophilization under controlled conditions and with respect to the activity of so-called 'protective colloids'. In this way it is hoped to gain further information upon the viability of *Rhizobium* in soil and dust with the possibility of application of these results to a dry-type inoculating medium instead of the liquid-type at present in current use.

6. *Publications.*—During the year, 32 Divisional reports dealing with small units of work not in complete form or of a confidential nature were prepared and circulated to interested bodies, and the following papers were published:—

Clarke, G. B., and Marshall, T. J. (1947).—The influence of cultivation on soil structure and its assessment in soils of variable mechanical composition. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 162-75.

Crocker, R. L. (1946).—The soils and vegetation of the Simpson Desert and its borders. *Trans. Roy. Soc. S. Aust.* 70: 235-58.

Downes, R. G. (1946).—Tunnelling erosion in North Eastern Victoria. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 283-92.

Gurr, C. G. (1947).—The freezing point of soil water in relation to the permanent wilting percentage. Ibid. 20: 105-109.

Harris, J. R. (1947).—Legume inoculation. *J. Dept. Agric. S. Aust.* 50: 447-54.

Hubble, G. D. (1947).—A soil survey of part of Waterhouse Estate, County of Dorset, North-East Tasmania. Coun. Sci. Ind. Res. (Aust.), Bull. 204.

Marshall, T. J. (1947).—Mechanical composition of soil in relation to field descriptions of texture. Coun. Sci. Ind. Res. (Aust.), Bull. 224.

Northcote, K. H. (1946).—A fossil soil from Kangaroo Island, South Australia. *Trans. Roy. Soc. S. Aust.* 70: 294-6.

Oertel, A. C., Prescott, J. A., and Stephens, C. G. (1946).—The influence of soil reaction on the availability of molybdenum to subterranean clover. *Aust. J. Sci.* 9: 27-8.

Oertel, A. C., and Stace, H. C. T. (1947).—A spectrochemical survey of some phosphate rocks and superphosphates. *J. Coun.. Sci. Ind. Res.* (Aust.) 20: 110–3.

Stephens, C. G. (1946).—The purpose and technique of land-use surveys in South Australia. *J. Aust. Inst, Agric. Sci.* 12: 128-9.

Stephens, C. G., and Crocker, R. L. (1946).—Compositions and genesis of lunettes. *Trans. Roy. Soc. S. Aust.* 70: 302-12.

Stephens, C. G. (1947).—Pedogenesis following the dissection of lateritic regions in southern Australia. Coun. Sci. Ind. Res. (Aust.), Bull. 206.

VII. IRRIGATION SETTLEMENT INVESTIGATIONS.

A. Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria.

1. *General.*—During the year, the staff has been brought to a strength beyond that of the pre-war period. The work of recently appointed members (five graduates) is naturally not yet reflected in any completed investigations; but this report indicates the directions in which they are working.

The dried fruit industry has now experienced three successive years of low production, for which there is complete evidence that seasonal conditions were responsible. The potential crop was in each year satisfactory, the reduction in the 1944-45 season being due to the withering effects of exceptionally hot dusty winds, and in the two subsequent seasons to rain on the ripening grapes. The potential yield for 1947-48 is lower than in any of the three previous years, but if realization of the potentialities follows, the yields will be higher.

The chief concern of the irrigated areas of the Murray River in recent years has been the decline in productivity of small portions in many important districts. Examination has shown that the decline in most cases is due to well recognized and well defined causes, associated with salt, seepage, or a combination of the two. In the light-textured horticultural areas, loss of productivity is directly attributed to the decrease in reclamation works during the war period in areas which were imperfectly or incompletely drained. In the heavier soils, used for pastures and fodders, overstocking during periods of drought, with its inevitable decrease in the plant cover necessary as a dewatering agent, has resulted in soil deterioration due to a rise in the underground water-table. Corrective measures are in hand in areas to which established methods of reclamation can be applied, and investigations are in progress in settlements in which the irrigation environment and the drainage response of the soil types are not yet sufficiently defined to warrant planning sub-surface drainage. Decreases in fruit production associated with soil decline are minor compared with losses due to unfavorable seasons, as decline in productivity is restricted to small areas.

Assistance has been given to Commonwealth and State authorities in locating suitable areas and planning for post-war land settlement for returned servicemen. These activities include minor soil surveys, selection of suitable locations for the crops to be grown, and economic considerations, including farm size and irrigation design.

A survey of water usage and distribution in the Red Cliffs settlement has been continued in co-operation with the State Rivers and Water Supply Commission of Victoria. The examination shows that the quantities of water applied to the land cannot conceivably be required by the plants grown. Devices and methods for the measurement of water under the conditions of usage have been studied, and measuring appliances adopted on an experimental scale.

Fruit processing requisites are still in short supply, including the vegetable oils used in dips for grapes. A sulphonated oil, "Sulphol", gave slightly better results than the vegetable oils, and was used to supplement the supply.

Vegetable work, for which the Station is a unit in comprehensive investigations of the Division of Plant Industry, has been extended and further developed. Variety trials of tomatoes, potatoes, and rock melons have been continued. An interesting phase is the development of tomato hybrids resistant to Fusarium wilt.

Biological investigations comprise the collection and identification of insects of the Mildura district, particularly those of economic importance. Trials of spray specifics have been hampered by the rarity of vineyard pests in the past season.

2. *Irrigation and Reclamation.*—A survey of current irrigation practice and methods of application of irrigation water and of subsoil drainage has been made by officers recently appointed. The purpose is to compare production methods with the standards envisaged by agricultural science. Some of the subsurface drains designed for soil preservation have not been sufficiently intensive. Extensions to cover reclamation needs have been investigated and the necessary modifications explored. A knowledge of the irrigation and reclamation requirements of Mallee soil types of the Murray districts has also been gained.

The trial and modification of means to measure irrigation water has proceeded, and a model suitable for experimental measurement has been developed. It consists of a rotor whose speed of revolution is related to the flow of water through a short length of pipe. The four blades of the rotor have a constant pitch and their leading edge is inclined at 45° away from the oncoming water so that rubbish will pass over the edge of the blade, clearance being for this purpose. Delay has occurred in obtaining facilities for the number of meters required for experimental use. Consideration has been given towards designing a meter more suitable for commercial measurement of irrigation water than those in present use.

Contact with the State Rivers and Water Supply Commission, Victoria, and the Water Conservation and Irrigation Commission, New South Wales, has been maintained, and arrangements are in hand to co-operate in the investigation of water usage and in service trials of the results of the enquiry. Preliminary work has been carried out on equipment for measuring the rate of entry of water into soils. Results from infiltration rate determinations are linked with investigations on the optimum water requirements of the major soil types of the irrigated districts.

In co-operation with officers of State Departments in Victoria surveys have been made of irrigated pasture lands in Swan Hill and Cohuna districts (Victoria), and in the Wakool district (New South Wales). The usual association of free subsoil water and the rise of injurious salts were noted on portions of the areas in which productivity was either lost or declining, and the work is being continued by State officers by the establishment of experimental areas on which the methods and the rate of reclamation are being studied.

3. *Land Use.*—Some minor soil survey work has been carried out, the Station having agreed with the Soils Division and with the Department of Agriculture to undertake local requests involving less than a week's field work, in order to save diversion of their efforts from major operations, to satisfy urgent soldier settlement requirements, and to maintain contact with local problems. So far 2,300 acres have been surveyed under these conditions, including 1,400 acres at South Merbein for the Department of Agriculture; the results have been reported to the authorities concerned and to the Soils Division.

This work has disclosed weaknesses in the knowledge of the relationship of citrus growth to management and to soil type, and a beginning has been made on collecting material for a better definition of this relationship. In the irrigation districts of Wakool seven experimental plots, on land representative of the major soil types of the district, have been established, for a study of the productivity as associated with the type of soil. The overall results for the first year indicate greater productivity in the soils of relatively

light texture, with also extreme variation in the productiivty of some of the soils of heavy texture, which appears to be related to soil structure.

4. *Horticulture.*—Iron chlorosis investigations have been continued; for currants there is increasing evidence to show that chlorotic vines can sometimes be cured or very considerably improved by restricting cultivation to occasional very shallow working to destroy weeds; and by swabbing all pruning cuts with a 20 per cent. ferrous sulphate solution. One plot of currants, in which the vines has ceased to bear fruit and were dying some two years ago, was treated in this manner and has continued to make good progress and last season bore a good crop.

Swabbing trials with minor elements on sultanas and currants were continued at the Research Station. Negative results have so far been obtained by swabbing all pruning cuts with concentrated solutions of salts containing boron, iron, manganese, zinc, and molybdenum. With Gordo vines, zinc treatment by swabbing pruning cuts with 20 per cent. zinc sulphate again gave an increase in yield on one plot at Red Cliffs.

Three general manurial trials on irrigated sultanas —one at the Station, one at Red Cliffs, and one at Woorinen—are maintained, and with their known history of treatment are to be used in an examination of chemical changes in soil under irrigation, for which other preliminary work is still being carried out.

For a study of the lack of uniformity of grapes of the Gordo Blanco, continuous study of the grapes, including growth records, were made from flowering time until maturity. After setting was complete, it was found that the grapes on the majority of bunches could be graded into three distinct classes—large berries with seeds, medium sized grapes with imperfect seeds, and small seedless grapes. Weekly measurements of size disclosed that both the large normal berries and the medium berries with imperfect seeds had regular growth characteristics, the chief differences being the size and the shape of the berries. At maturation, they constituted two distinct classes.

The annual examination of the buds on sultana canes of the Mildura district revealed a decrease in the average bud fruitfulness and also in the average primordia size. There was very little difference in either fruitfulness or primordia size between canes examined from frosted and non-frosted areas in the Woorinen district. The percentage of fruitful buds has provided a reliable estimate of yields, except in seasons when losses from various production hazards have been heavy.

On a manurial trial on citrus at Merbein, which is being carried out in co-operation with the Department of Agriculture, a growth census of one shoot from each of 100 trees covering the various treatments, has been started. In this connexion a relation between growth cycle and deficiency symptoms has been noted.

The testing of a fan for frost damage prevention, designed by the Council's Division of Aeronautics, was undertaken during the spring of 1946; results warranted further investigations during the winter of 1947. A site has been prepared for the test in a vineyard known to be affected by frost. Preparations include the installation of Sanborn Element thermometers (i) exposed to imitate the radiation characteristics of a young vine shoot, and (ii) aspirated to measure actual air temperatures. Psychrometer Sanborn apparatus together with balloon gear is also available to determine the temperature and the humidity of the air immediately above the site of the test.

5. *Vegetables.*—Vegetable investigations have been carried out at the Merbein Station in close co-operation with the Vegetable Section of the Division of Plant Industry. Most of the work is carried out on an area of land in the Red Cliffs district where an urban water supply is available for both furrow and spray irrigation. In addition, the plot is served by a pipe line from a State Rivers and Water Supply channel where water can be obtained during the irrigation periods for vines. Investigations have concerned tomatoes, potatoes, carrots, red beet, rock melons, and beans, and results obtained to date are being assembled for publication.

With regard to tomatoes, many new varieties and hybrids have been tried under irrigation conditions in this district. Pearson 29-17 has proved an outstanding variety for both yield and quality over the last four years. The most promising hybrids tried to date are those varieties that have been crossed with Pan America, a variety fairly resistant to Fusarium wilt disease. This disease causes extensive losses in some seasons in the Mildura district. Of the hybrids so far tested, Rouge de Marmande x Pan America and (Vetomold C x Rouge de Marmande) x Pan America appear the most suitable. Arrangements have now been made for the Victorian Department of Agriculture to conduct commercial plots of these hybrids in this district for further observation. If considered suitable, seed will be released to growers. Other varieties of tomatoes considered suitable as regards yielding ability and quality were crossed during the year and seed collected for further studies.

Several varieties of potatoes have been tested, and all have been more or less affected by Fusarium wilt during the growing season. Most varieties also produced undesirable second growth tubers. Varieties, however, which showed promise under irrigation conditions in this district are Katahdin, Pontiac, Kusota, Houma, Sebago, and Sequoia.

With regard to carrots, some 42 varieties and strains, the seed of which was obtained from various seed merchants, have been investigated. Duplicate plots of each variety and strain were sown during the winter and spring. Results disclosed that there were significant differences for both yield and quality between strains of the same variety as well as between different varieties. Seed sown during the spring produced higher yields than seed sown during the winter. The percentage of roots that split was much higher for the winter-sown seed than the spring-sown seed, and no unusual seasonal conditions to which this could be attributed were noted.

Duplicate plots of thirteen varieties and strains of red beet were established during the winter and spring. A strain of Early Wonder Tall Top proved the most suitable for both sowings. With winter-sown seed, all varieties and strains (with the exception of two) had a percentage of plants that seeded. No plants from seed sown during the spring seeded. The percentage of roots that split was much higher with the winter sowing than spring sowing.

Many varieties of rock melons new to the district have been tried. Some of these show promise of being suitable for growing under irrigation conditions in the Murray Valley.

Studies of the growth of bush and climbing beans have been continued. Brown Beauty has been the principal variety grown in the district, and has proved quite suitable. However, with a view to investigating the suitability of other varieties, trials were carried out on seven bush varieties, including Brown Beauty. Growth studies carried out included times of flowering, times of setting, percentage of pods of total flowers, maturity size of pods, and cooking qualities. Wellington Wonder and Hawkesbury Wonder were the highest yielders, while New Zealand Stringless Greenpod and Logan were best for cooking qualities.

Studies on the periodicity of irrigation for tomatoes, have been continued and extended to include further treatments. Treatments now include watering plants (furrow irrigation) at 1, 3, 4, and 5 weekly intervals. Data are at present being examined, but Fusarium wilt affected many plants in the trial last year and may have to some extent masked results.

At the request of the Division of Plant Industry, small preliminary plots of soy beans were commenced in 1947, to study the growth habits of various varieties when grown under irrigation. Records of yield and growth indicate that some of the varieties tested may prove suitable. Some varieties, however, failed to mature.

In conjunction with the tomato variety trial conducted at Red Cliffs, the vitamin content of each variety was estimated on 18th February, and 5th March, 1947. The eight hybrid varieties contained as much ascorbic acid as the four standard varieties in the trial. The results obtained were higher than last season's and comparable with the figures for 1944-145.

6. *Fruit Processing.*—Investigations were continued on the use of special sulphonated oils and wetting agents in the dipping and drying of sultanas, and the stage has been reached where it has been shown that certain specially prepared sulphonated oils give slightly better results than the vegetable oil emulsions which have been in general use. When supplies of vegetable oil were unavailable last season the use of a special sulphonated "Oleine" was recommended. This was sold under the trade name "Sulphol". Latest results suggest that it may be possible to use paraffin oil in dipping if special wetting agents are used in conjunction with it.

Further investigations were carried out on the use of potassium hydroxide (caustic potash) in spray mixtures for hastening the drying of cold-dipped sultanas. These have shown that during slow-drying weather potassium hydroxide is much more effective than potassium carbonate, but that during good weather the difference is not so great. Spraying with caustic potash browns the fruit more than carbonate of potash. In the Woorinen district spraying trials were carried out with both the mixed and cold dips.

Investigations were continued on the control of mould growth on fruit drying on the racks. These showed that mould growth in currants could be checked by enclosing the rack with "Jutex" or similar side curtains and sulphuring the fruit for one to two hours with the fumes of burning sulphur produced by burning approximately 2 lb. of sulphur in a suitable container under every second bay. Light sulphuring in this manner caused no appreciable bleaching.

Work is in progress on the packing-house treatment of rain-damaged fruit, and in particular the treatment of currants affected with mould. A washing procedure has been devised which removes approximately 90 per cent. of the mould spores present. The condition of the fruit this season emphasizes the necessity for the thorough washing and drying of all dried fruits in the packing houses prior to packing, and work has been commenced with the object of finding the most efficient method of incorporating this treatment in the standard production line.

Investigations were also carried out on the spoilage of dried fruit in certain food parcels sent to Britain, and on the use of moisture-proof cartons for dried fruits. A report covering this work was submitted to the Export Control Board.

A study was made of the use of hessian wicks and of sodium nitrate as aids to the burning of American powdered sulphur in the sulphuring of tree fruits. A summary was presented to the (Interstate) Dried Fruits Processing Committee.

Drying trials with infra-red rays were carried out in co-operation with the Red Cliffs Co-operative Packing Co., and a report on this work was prepared. The results showed that freshly washed fruit could be thoroughly dried in about fifteen minutes but that the cost was likely to be high.

7. *Biology.*—Preliminary trials were commenced using Atlacide and Methoxone as weed-killers on bindweed (*Convolvulus arvensis*), hoary cress (*Lepidium Draba*), and hardheads (*Centaurea picris* syn. *repens*). Apparently good results were obtained with the first two weeds but hardheads proved more resistant, for with it time of application seems to be very important. It was found that spraying of box-thorn trees killed the leaves alone and they were replaced by the tree on three occasions in three months with no ill effects to the tree. A currant vine was easily killed when sprayed with Methoxone.

Although several insecticides were applied in a trial to combat the light brown apple moth (*Tortrix postvittana* Walk.) on grape vines, only the preliminary sprays were applied, as the apple moth population did not build up to pest proportions and in the latter part of the season was almost wholly absent.

Insects belonging to the following orders have been collected and where possible identified: Hymenoptera, Diptera, Lepidoptera, Coleoptra, and Orthoptera.

8. *Finance.*—The station is partly financed by the Treasury and partly by other organizations. Contributions received during the year included £1,200 from the Dried Fruits Control Board and £1,000 from the Mildura Packers' Association. Other contributing bodies comprise the State Rivers and Water Supply Commission of Victoria, the Water Conservation and Irrigation Commission, New South Wales, the Rural Bank of New South Wales, and several producers' organizations for examination of special problems of their districts.

B. Irrigation Research Station (Murrumbidgee Irrigation Area), Griffith, New South Wales.

1. *General.*—The Irrigation Research Station at Griffith was established in 1924. It has 140 acres of irrigable land, 30 acres of which are planted to orchard trees. During the past year, extensive additions have been made to the laboratories, which now provide excellent facilities for research.

2. *Field Experiments with Fruit Trees.*—Permanent field experiments with orange trees cover investigations of the following:—Methods of irrigation and water requirements of trees, fertilizer requirements, including trace elements, cultural treatments, and other studies.

Besides these experimental fields on the station's property, there are experimental plots on settlers' orchards. Much information concerning suitable methods of irrigation for different soil types and the effect of different cultural treatments on tree growth has been obtained from these plots.

Zinc deficiency following on the application of superphosphate to the soil often leads to serious unthriftiness in trees. The reason for this effect of the phosphate ion on the availability of zinc to the plant is being studied. A study of the root systems of fruit trees has shown that soil texture exerts some influence on the distribution of the roots, but other factors, such as cultural methods adopted, overshadow the effect of soil texture.

3. *Irrigation Investigations.*—For better understanding of the principles involved in the infiltration of water from furrows and its lateral soakage, experiments were continued using short sections of furrows of different shapes and containing different quantities of water.

The results to hand show the importance of close spacing of furrows, in order to effect economy in the use of water. The furrow shape and size within the irrigated strip is of secondary importance except when the shape of the furrow brings the water rather close to the plants irrigated.

These results are of importance in designing suitable irrigation layouts for the wide range of slopes and soil conditions which obtain in practice, and are especially important when considering the exacting requirements of vegetable growing.

4. *Rice Field Investigations.*—Rice-growing is rather extravagant in the use of water, and with a limited supply of water for irrigation this aspect of the industry constitutes an important problem. On some parts of the irrigation areas sandbeds underlie the soil, and excessive infiltration to these beds is a serious menace to neighbouring horticultural districts. An investigation to determine the amount of water lost to the atmosphere from paddy fields by transpiration and evaporation, and the amount that infiltrates into the soil, under the varying conditions that obtain, was carried out during the past rice season. The results are important in determining future policy in the use of water for rice-growing.

5. *Drainage Investigations.*—Waterlogging and salting are widespread on the Murrumbidgee Irrigation Area, and are threatening the commercial life of many farms. Drainability studies on the major soil types have been continued to determine the optimum depth and spacing of tile drains. The information supplied by these studies is being used as a basis for the installation of farm-size tile drainage trials on each of two major soil types. The effects of drainage on crop and on soil-salt status will be studied. Two suitable farms have been selected for these trials. Mole drainage investigations are proceeding. The possible use of salted horticultural land for dairying purposes is being explored, and methods of establishing and maintaining pastures on such land are being worked out. Such factors as width of bay, length of run, and pasture mixtures are being considered.

6. *Soil Reconditioning Investigations.*—The average life of orchards is about twenty years, and as most of the plantings on the Murrumbidgee Irrigation Area are now twenty to 30 years old, the district has passed through the first cycle of its development, and the use of old orchard land presents some problems.

The constant tillage and working of the land results in the loss of crumb-structure and the formation of a plough sole; these cause a decline in the fertility of the soil. Investigations are proceeding to determine the exact nature of these soil-structural changes, how they can be prevented, and how the structure of soils so affected can be improved.

7. *Salt Investigations.*—Work on the diagnosis of salting in orchards shows that foliar analysis is more reliable than soil analysis and that, by the use of a quick method, an overall saving of time can be achieved. The chloride ion has proved to be an effective indicator, but further work is in progress for cases where sulphates are important.

In collaboration with the Water Conservation and Irrigation Commission, the composition of drainage waters pumped from deep sand beds under the Yanco area has been followed from month to month. The good quality of Murrumbidgee Irrigation Area irrigation water has been established, and the fluctuations in composition determined, over one irrigation season.

8. *Vegetable Investigations.*—During the past year, investigations in the field have centred on the nitrogen and phosphorus nutrition of the main vegetables grown on the Murrumbidgee Irrigation Area. Short-term and long-term experiments to study the fate of superphosphate applied to soils under irrigation are in progress. The degree of fixation of phosphates and their rate of accumulation under commercial vegetable culture, in conjunction with leaf analysis and yield measurements, will point the way to sounder recommendations for the use of phosphatic fertilizers. Further aspects of the dominating influence of fallowing on the nitrogen requirements of vegetable crops have been investigated. It has been shown that there is a carry-over of the accumulated nitrates from a fallow in the previous summer to the succeeding season for both spring and autumn crops.

Two experiments were carried out on salty land to compare farrow and spray systems of irrigation under these conditions. Spray irrigation showed to advantage on the two soil types, a clay loam and a sandy loam.

Material has been grown for dehydration and biochemical studies by the Division of Food Preservation and small trials carried out for various sections of the Division of Plant Industry.

9. *Plant Physiology.*—A study is being made of the problem of soil structure in relation to organic manures, using the crop itself as a guide to soil conditions. Rice hulls—a by-product of the local rice mill—were used as an organic manure for tomatoes. The initial project established a positive effect of rice hulls, even without additional nitrogen, on the yield of fruit. However, this result followed a very pronounced depression in early growth with the same treatment. A study of the establishment and early growth of the plants with a wider range of treatment is in progress.

In field experiments, especially with organic manures, consistent treatment effects on yield are often difficult to get. This is due to the complexity of the circumstances which obtain from time to time and at different sites. Final success in interpretation would seem to depend upon a simultaneous study of the changes in the soil, and in the crop which it supports. The physiological aspects of such a programme call for the development of plant sampling techniques which attain at least as high a degree of precision as that now obtainable under the relatively controlled conditions of the glass-house. The work on this technical problem has occupied much of the current year, and very satisfactory progress has been made.

Work has begun on the water relations of plants. The initial project is a study of the effects of mild and severe wilting on the subsequent growth of individual parts of young tomato plants.

10. *Frost Investigations.*—A survey of the "frostiness" of the Northern Lake View district on the Murrumbidgee Irrigation Area is being carried out. The suitability of the district for horticulture depends on its relative "frostiness", and this must be determined before it can be said that the area is suitable for horticulture. The method adopted consists in exposing minimum thermometers distributed systematically over the area and comparing the readings with those obtained on already settled areas.

In co-operation with officers of the Division of Radiophysics, temperatures on calm clear nights are being recorded at levels up to 400 feet by means of a sounding balloon. The nature of the "temperature inversion" so recorded is of importance in developing methods to combat frosts.

11. *Soils and Irrigation Extension Service.*—By arrangement with the New South Wales Department of Agriculture, the Council has undertaken a programme of education and extension work to bring the results of investigations of soil-water relationships and irrigation methods to the irrigation farmers. The work was inaugurated in 1943 for a period of three years. The precise form of its organization for future years is at present under consideration with a view to the Department of Agriculture taking over the responsibility for it.

The policy of the service is directed by the Advisory Committee of the Research Station, representing local farmer interests and State and Federal organizations concerned with agriculture on the Murrumbidgee Irrigation Area. All these organizations contribute to the cost of the service. Details of the work are given in mimeographed progress reports available from the research station.

The service has concentrated on more urgent district problems chiefly, controlled irrigation to prevent salting, reclamation of salted land, and cultural

practices to maintain soil fertility. The aim of extension work must be to contact every member of the farming community to see that research and other information is applied on every farm. A proved requirement for effective extension work is the full participation of local farmers in its planning and conduct, and the Soils and Irrigation Extension Service has co-operated with the New South Wales Department of Agriculture in assisting farmers to form eight district extension groups, which are now organized on a regional basis through the Murrumbidgee Irrigation Area District Council of Extension Groups.

In addition to farm visits, the methods used include the holding of field days, farmers' extension schools, lectures at meetings of extension groups and at general farmers' meetings, weekly press articles and broadcasts, and the periodical publication of a Farmers' Newsletter. Visual education methods, including the use of an epidiascope and a sound-film projector, greatly increase the effectiveness of the work. Special courses for Junior Farmers are conducted.

During 1946-1947, the future of the Extension Service has been under consideration by the contributing organizations. The Advisory Committee to the Research Station has prepared a report, with detailed recommendations for co-ordinating research and integrating extension on a regional basis. In this, the experience of the past four years has been used to draw up recommendations aiming to use the Murrumbidgee Irrigation Area as a testing ground for modern principles and techniques of agricultural organization.

VIII. FOREST PRODUCTS INVESTIGATIONS.

1. *Introduction.*—At the beginning of the year under review a rather ambitious programme of work covering some 170 projects and sub-projects was drawn up. A great number may be considered as recurring projects likely to extend over many years, while others were listed in the hope that during the year a start could be made on some outstanding problems. The delay has been almost entirely due to the difficulties in procuring suitable research and technical officer staff. However, it is pleasing to report considerable progress in many lines of work and to record that attention has been devoted to many projects of a fundamental nature, without neglecting the all-important maintenance of contact with the timber industry.

Throughout the year co-operation has been maintained between the State Forest Services and the Commonwealth Forestry and Timber Bureau. It has been officially agreed that the Division will co-operate with the newly-formed Forests Department of the Papua-New Guinea Administration in the same way as it does with the various State Forest Services.

Fundamental studies on wood chemistry and pulp and paper problems have been continued throughout the year in co-operation with the pulp and paper industry. At the Eighth Annual Pulp and Paper Co-operative Research Conference, held in March, 1947, New Zealand Forest Products Ltd. was represented for the first time. This research conference was timed to coincide with the first annual meeting of the Australian Pulp and Paper Industry Technical Association—a body that will supply the much overdue opportunity for co-operation and exchange of ideas between all technical personnel of the pulp and paper industry on a much broader scale than that which concerns fundamental research. The Research Conference and the Technical Association will function independently although there will naturally be close liaison between them.

The Division has for some years recognized that the industrial and economic development of the timber industry in Australia is seriously handicapped by the absence of data covering the inter-relationship of production rates, sawn recoveries, and conversion methods, with type of equipment used in Australian saw-mills and the influence of these factors on saw-mill design. Therefore, with the object of accumulating the requisite background and information necessary to undertake an examination of saw-mill design, saw-mill studies have been carried out by the Division in Queensland in co-operation with Queensland Sub-Department of Forestry and the Queensland Timber Stabilization Board, and in Victoria in co-operation with the Victorian Saw-millers' Association.

Officers of the Division have again been called upon to give numerous lectures on forest products. These have included public lectures, lectures to various rehabilitation classes, and lectures to the forestry students of the University of Melbourne. A successful kiln-seasoning course was held in February, 1947, in Adelaide and was attended by manual training instructors of the South Australian Education Department, kiln operators, and others of the timber industry in that State. It was arranged by the South Australian Branch of the Timber Development Association.

The publication of the Forest Products *News Letter* has been continued throughout the year. The *News Letter* has been given wide circulation and through it the work of the Division has become known, not only to the general public in Australia, but also in other parts of the world. In addition, the internal reports prepared by the officers of the Division have in recent years been given a somewhat wider circulation and, by this means, the work of the Division has received attention over a wide field.

Two senior officers of the Division spent a considerable time in Japan as members of the Australian Scientific Mission.

The Division was represented at the Fifth British Commonwealth Forestry Conference held in London in June, 1947, by the Chief of the Division and the Officer-in-Charge of the Wood Structure Section.

The number of inquiries received from trade, government, and semi-government sources has increased considerably. Over 3,000 such inquiries, in addition to those covered by correspondence, were handled.

2. *Wood Structure.*—(i) *Cell Wall and Fibre Studies.*—(*a*) *The nature of the cell wall.*—In order to obtain further evidence on the micellar angle, the various layers of the cell wall were investigated by the following methods:—the microscopic appearance of fibre and tracheid walls after crushing; the behaviour of cross sections when viewed by means of the ultra-microscope; the comparative dichroism of various cell types; the comparative birefringence of various cell types.

(*b*) *Collapse.*—It has been felt for some time that one method of investigating collapse, particularly that which does not recover during a standard steaming process, was by investigation of cell wall structure. Tension wood specimens collapse very badly and show little or no recovery. It was considered that this would perhaps give some lead as to the relationship between the physical and chemical nature of the cell wall and extent of collapse. The cell wall of tension wood fibres is known to be low in lignin by comparison with that of normal wood fibres of the same tree. Hence it is possible that recovery under steaming may be directly correlated with the lignin content. Tests are being carried out to explore this possibility. A technique has been developed whereby sections of collapsed wood can be cut without immediate recovery occurring.

(*c*) *Compression wood tracheids and tension wood fibres.*—In the determination of the longitudinal shrinkage of isolated fibres, no significant difference has been observed between tension wood fibres and normal wood fibres from the same growth ring in

the same tree. Similar results were obtained with compression wood tracheids and normal wood tracheids, while measurements carried out at the same time showed that the micellar angle of the compression wood tracheids was on the average much higher in relation to the longitudinal fibre axis than that of normal wood tracheids taken from the same relative position in the growth ring. Different methods of isolating the free fibres were employed and measurements were carried out in water, in alcohol, and in xylol. It has been concluded that there is no direct relationship between micelle angle and the longitudinal shrinkage of the fibres after removal of water. The abnormally high longitudinal shrinkage of reaction wood must be explained on other grounds, and it is suggested that the nature of the intercellular layer and the relative chemical composition of the cell walls might have some bearing.

(ii) *Growth Studies.* — (*a*) *Eucalyptus spp.* — The growth of *E. regnans* F.v.M. as represented by increase in the woody tissue of the stem is apparently continuous throughout the year, although not uniformly at the same rate. There is no evidence of cessation of growth at any period either in summer or winter. Rather similar results were obtained with *E. gigantea* Hook f., although with this species there is a definite formation of so-called latewood quite late in the winter and just prior to the commencement of spring growth. The change to latewood and then to earlywood is very rapid, and apparently occurs in late August or early September.

(*b*) *Pinus spp.*—With *P. radiata* D. Don and *P. ponderosa* Doug., latewood formation begins at the end of May in most of the trees examined; in a few this formation was a month later. Latewood was continuously laid down in all trees throughout June, July, and the early part of August, and the next season's earlywood was first discernible in late August or early September. There is apparently little or no resting period.

(*c*) *Species from N. Queensland.*—The determination of the amount and nature of the woody tissue laid down by the five species selected for examination has been extremely troublesome because of the difficulty of correlating the growth from month to month. Following the original plan, the monthly specimens were collected in rotation from north, south, east, and west sides of the one tree. In some trees it has been found possible to correlate specimens taken from the same side and from these some results have been obtained. However, it has been decided to change the plan of collection to cover one side of each tree only. A preliminary survey of the results shows that supposedly terminal parenchyma bands are laid down very irregularly and apparently at no particular time in the growing season.

(iii) *Wood Anatomical Investigations.* — (*a*) *Myrtaceae.*—For the revision of the earlier work on the coloured commercial eucalypts (Bulletin 67) numerous low-power photomicrographs have been prepared of the cross sections of the various timbers to show details of structure. These, when incorporated in the revised publication, will prove of considerable assistance in macroscopic identification. Following the examination of these and other eucalypt timbers, a card-sorting key based on macroscopic features only has been developed. This is intended in the first place for laboratory use and will not be for general distribution. A short article has been published on the results of the examination of the woods of the genera *Syzygium, Acmena,* and *Cleistocalyx* in comparison with those of the genus *Eugenia* (restricted mainly to the New World according to Merrill and Perry).

(*b*) *Photographic record of anatomical features.*—The preparation of an atlas of photomicrographs of the various commercial Australian timbers is in hand. The features of each species will be shown in cross section at both low and high power, in tangential section, and in radial section.

(iv) *Identifications.*—Over 1150 timber and fibre identifications have been completed during the year. Many of the timbers submitted came from the various Pacific islands, and it is evident that the Australian timber trade is looking to this source for future supplies. Numerous requests were received for the identification of the fibrous raw material used in the manufacture of boards of various kinds and of paper products.

(v) *Timbers of the South-West Pacific Area.*—(*a*) *New Guinea.*—The examination of various species has been continued. A working plan for a proposed series of publications on New Guinea timber species has been drawn up in collaboration with Mr. J. B. McAdam, Secretary, Forests Department, New Guinea—Papua Administration, and Mr. C. T. White, Government Botanist, Brisbane. Some 25 of the more important species will be covered in the first bulletin. For this work the necessary timber descriptions covering macroscopic and microscopic features have been prepared. Information on the forestry and botanical aspects will be supplied by Mr. J. B. McAdam and Mr. C. T. White respectively. The collection of information from all sources has been centred in this Division.

(*b*) *British Solomon Islands Protectorate.* — The examination of the timbers from this region has been completed and the results forwarded to Mr. F. S. Walker who conducted the forest survey for the High Commissioner of the Western Pacific. Discussions on the timbers and methods for their identification were held with Mr. Walker when he visited the Division at the end of 1946.

(vi) *Card-Sorting Identification Keys using Macroscopic Features.*—The revised key for New Guinea timbers has been completed and 200 sets prepared. Many of these have already been distributed. The key for the Australian commercial timbers has been practically completed, all the information for the individual species being prepared and in the printer's hands. During the year, arrangements were made to include on the card for each timber species botanical information and line drawings of leaves, flowers, and fruits. A record of the work carried out during the war on the preparation of various card-sorting keys for use by the fighting services has been prepared for publication.

(vii) *Reaction Wood.*—In collaboration with the Division of Industrial Chemistry, X-ray diffraction patterns have been obtained of tension wood in comparison with normal wood, and of compression wood in comparison with normal wood (early and latewood). The tension wood pattern gave evidence of high micellar orientation and this was correlated with the thick inner layer of the secondary wall so characteristic of tension wood fibres. This layer is practically pure cellulose. Further experiments have been carried out, in co-operation with the Commonwealth Forestry and Timber Bureau, on the development of tension wood in young saplings. In young stems of *E. melliodora* A. Cunn. which were pulled from the vertical, tension wood had developed in all trees in 16 days and, in some cases, could be definitely detected in twelve days. It was not possible to follow the actual stages in the development of the tension wood fibres, although there appeared to be an "incipient" stage.

(viii) *Sapwood-Truewood (Heartwood) Transformation.*—The investigations in this field have been confined mainly to the genus *Eucalyptus,* although some Queensland timbers with a wide zone of intermediate wood have also been studied. In an attempt to find a reliable method of distinguishing sapwood from truewood in species in which the truewood is not coloured and in those in which the truewood vessels are not

commonly plugged by tyloses, a preliminary survey was made of some 40 eucalypt timbers. It was found that sodium nitrite reacts with woods which contain tannins of the "depside" group to give a colour reaction which is pink at first, but rapidly changes to blue on exposure to the air. The occurrence of this stain has been correlated with anatomical features of the truewood and it is now used as an indication of the presence of truewood. Truewood formation starts at a very early stage in some species of *Eucalyptus*, trees of *E. regnans* six and a half years old having already formed a considerable amount. Saplings are now being studied in order to establish at what age and under what conditions truewood begins to form as well as its relation to the crown and to the branching of the tree. Among the Queensland timbers investigated were three species of the genus *Argyrodendron* (tulip oaks). Starch was observed to be present in considerable quantity throughout most of the so-called intermediate zone, and small amounts were present at about 1½ in. from the centre of the trees examined. It seems probable that this genus does not complete truewood formation until the trees attain considerable size, and that most of the wood formed is of an intermediate character. At present a new aspect of the investigation is developing through the study of branch material. Truewood formation appears to be the result of a stimulus from the crown downwards and patches of truewood are formed at branch bases above the limit of truewood in the main stem. The significance of this is not yet understood but it is possible that there is some connexion between this and the shedding of old branches by some species of eucalypts.

(ix) *Photography.*—(*a*) Further experiments have been carried out using a high-speed movie camera for revealing the action during the tearing of a piece of paper. This field of work holds promise of interesting results.

(*b*) The photographic work of the Division is still extensive and during the year some 60,000 enlargements and 4,000 prints were handled.

3. *Wood Chemistry.*—(i) *Lignin.*—(*a*) *Methanol extraction of E. regnans sawdust in bulk.*—Methanol extraction, at 150° C., of *E. regnans* sawdust has been successfully undertaken on a 1 kg. scale to yield approximately two-thirds of all the lignin present in the wood. Although this lignin virtually has a constant methoxyl content (26 per cent.), it is not yet regarded as sufficiently homogeneous to be used for the investigation of molecular weight, constitution, and chemical reactions of wood lignin.

(*b*) *Nature of methanol extraction process.*—Methanol extraction of wood lignin is not a simple extraction process. Organic acids, mainly acetic acid derived from the acetyl groups of the carbohydrate fraction, are continuously liberated during the extraction. Although most of these liberated acids are rapidly converted to the methyl ester, there is present, at any given time, sufficient free acid to function as a catalytic or hydrolytic agent. It is most probable that the free acid causes hydrolytic fission between lignin and carbohydrates, thus freeing the lignin for extraction by methanol. Not all the lignin in wood is freed and subsequently extracted in this way. Hence methanol extraction of wood at elevated temperatures, such as at 150° C., must be regarded as a mild methanolysis process in which acids derived from the wood itself play an important catalytic or hydrolytic role.

(*c*) *Precipitation of methanol-extracted lignin.*—Electrophoresis experiments on colloidal lignins have shown that the particles are negatively charged and that they are readily precipitated by the addition of inorganic salts. Considerable attention has been given to the precipitation of lignin from its methanol solution with the object of establishing a reliable empirical method which could be employed for the estimation of lignin in the methanol extracts. Strict control of precipitating conditions is necessary. Lignins precipitated at low pH values have high methoxyl contents. The yield of precipitated lignin depends on its concentration in the precipitation medium, the volume of residual methanol, the time elapsing after precipitation, and the volume of wash water used.

(*d*) *Lignin-carbohydrate complex.*—Indirect evidence, in various forms, has been obtained of the existence of a lignin-carbohydrate complex in which approximately one-half of the total wood lignin is involved. The polyuronide constituent of the complex has been isolated from the final methanol extraction residue by extracting the latter with hot water followed by precipitation in alcohol. This material is now under investigation.

(ii) *Carbohydrates.*—(*a*) *Influence of bleaching and refining treatments on molecular weight frequency curves.*—Samples of eucalypt pulps, taken at various stages of the bleaching and refining process, when examined by the method of Ekenstam, have revealed no large variation in the shape of the molecular weight frequency curves throughout the process.

(*b*) *Alkaline degradation of holocellulose.*—Earlier work on the molecular weight distribution in various holocellulose fractions had indicated that xylose units may be scattered at random throughout the length of the cellulose chain. Further work was carried out in this field during the year.

(*c*) *Acid degradation of holocellulose.*—When boiled with dilute oxalic acid solution, according to the method of Haworth for hydrolysis of arabofuranose linkages in esparto grass, holocellulose breaks down extensively in chain length. When boiled vigorously with water for some time, holocellulose has been found to undergo a similar breakdown. The latter, at first, was attributed to the release of acetyl groups in sufficient quantity to cause acid hydrolysis. However, it has been revealed that the low pH recorded (2.6) was most likely due to hydrochloric acid which had been retained in traceable quantities after the holocellulose process, and that insufficient acetyl was liberated to account for the observed pH.

(*d*) *Fractionation of nitration products from wood and holocellulose.*—Since phosphoric acid does not dissolve cellulose which has a degree of polymerization in excess of 1,200, the use of this reagent in studying molecular weight distribution, according to the method of Ekenstam, is limited to materials having a relatively low degree of polymerization. For instance, holocellulose has been shown to contain 74 per cent. of material which is insoluble in phosphoric acid and which, therefore, could not be investigated by this method. The only method by which all the wood carbohydrates may be investigated is to convert them to their respective nitrates and to fractionate the latter by fractional dissolution using mixed solvents. Preparation of nitrated products from wood and holocellulose is in progress.

(iii) *Wood Hydrolysis.*—Attempts have been made to determine the partition of wood hemicelluloses between the orientated and amorphous regions, by studying the time-loss curves during hydrolysis of wood with sulphuric acid and by estimating the alkali-solubility of wood hydrolysis residues after these have been methylenated.

(iv) *Wood Chemistry.*—(*a*) *Tension wood.*—Tension wood of *E. regnans* contains more cellulose, less pentosan, and less lignin than does the corresponding normal wood.

(*b*) *Determination of free carboxyl groups in pulps.*—The iodide-iodate method, suggested by Ludtke, may be used with considerable accuracy to determine carboxyl groups in eucalypt pulps. Values are comparable with those given by the calcium acetate and silver o-nitrophenolate methods.

(v) *Pulp Evaluation Studies.*—(*a*) *Variables in hand-sheet making.*—Properties of hand-sheets of long-fibred pulps are not significantly influenced by considerable variations in the duration of the first pressing or in the time taken to reach maximum pressure. The time which elapses between processing and sheet-making does not significantly influence the properties of hand-sheets made from eucalypt kraft or from long-fibred pulps. Freeness values of beaten pulps increase significantly with the time elapsing between beating and the freeness test.

(*b*) *Washing of pulps before evaluation.*—Removal of pulp mill process salts from eucalypt kraft causes significant decreases in the strength properties of hand-sheets. Pulps washed with 0.1 N hydrochloric acid and distilled water are affected more than pulps washed with distilled water only. Washed pulps evaluated in distilled water give hand-sheets of lower strength than do those evaluated in a soft town water. Eucalypt kraft pulps are more sensitive to the nature of the evaluation process water than are eucalypt soda pulps. Where cation effects are significant, e.g., those of trivalent cations as represented by cerium, water-washed and acid-water-washed pulps are equally sensitive to the cation effects even though they may differ initially in strength properties as a result of the washing treatment.

(*c*) *Influence of cations on acid-washed soda pulp.*—Trivalent cations significantly decrease the strength properties of hand-sheets made from acid-washed eucalypt soda pulp processed in their presence. Uni- and di-valent cations have no effect.

(*d*) *Influence of carboxyl groups.*—Induced changes in free carboxyl content of a eucalypt soda pulp did not make it more sensitive to cation effects.

(*e*) *Influence of pH on pulp properties.*—Acid-water-washed eucalypt kraft is intrinsically acidic and its suspension in distilled water has a low pH (4.6). The use of such a pulp tends to obscure the effects when attempts are made to study the influence of pH on pulp properties by adding known amounts of acid. The use of a water-washed soda pulp has overcome these difficulties. Freeness values increase significantly with increase of acid concentration. Bursting and tensile strengths are only significantly influenced when the acid concentration reaches 40 p.p.m. of sulphuric acid (pH 3.5). Investigation beyond this point has not been attempted because of the corrosive action of the acid on the pulp evaluation equipment. Up to this point tearing resistance is not affected by the hydrogen ion concentration.

(*f*) *Combined influence of hydrogen ion and trivalent cation on pulp properties.*—It has not been possible to differentiate between the effects of hydrogen ion and a trivalent cation when these are both present as the result of hydrolysis of a trivalent salt, e.g., aluminium chloride. However, a mixture of cerium chloride (50 p.p.m.) and sulphuric acid (40 p.p.m.) had no greater effect on a eucalypt kraft pulp than had each of these when they were used separately at their respective concentrations. Hence the effects are definitely not additive.

(*g*) *Buffering of cation effects with aluminium sulphate.*—It is not possible to buffer or swamp cation effects by using relatively excessive amounts of aluminium sulphate. Observed differences when a eucalypt pulp was evaluated in hard and soft waters persisted when aluminium sulphate was added. The effect of aluminium sulphate was purely additive in each case.

(*h*) *Calibration of freeness plates.*—Fourteen freeness plates, used as reference standards by the pulp and paper industry, have been checked against sub-standards which were recently received from the Canadian Pulp and Paper Research Institute. In this work, a wide range of beaten and unbeaten pulps has been used.

(*i*) *"Unit sheets" for research purposes.*—A technique has been developed for the preparation of "unit sheets". These are hand-made sheets which have a thickness equivalent to that of two fibres, and which are uniform, homogeneous in formation, with fibres in a random arrangement. They permit transmission of light with the minimum amount of scattering. With these it is hoped to open up the field of sheet structure, factors affecting it, and of the fundamentals of the various physical tests to which a hand sheet is applied. The sheets are comparable with the finer types of hand-made tissues manufactured from kozo fibre by the Japanese.

(vi) *Paper Testing.—Correlation of paper testing equipment.*—Attempts have been made to correlate the various types of paper testing instruments which are being used by the pulp and paper industry and by the Division of Forest Products. This work has been handicapped by varying atmospheric conditions in paper testing rooms, by changes in moisture content while paper samples were in transit, and by the greater sensitivity of some papers to changes in atmospheric conditions.

4. *Timber Physics.*—(i) *General.*—During the year additional laboratories have been fitted out—one for work on the general physical properties of wood and one for dielectric heating studies and for work on the electrical properties of wood. Equipment has been obtained or constructed within the Division in order to calibrate instruments for measuring length, mass, temperature, and certain electrical quantities for the Division as a whole. Numerous calibrations of dial gauges, micrometers, thermometers, and electrical instruments have already been completed. Arrangements have been made for a periodical check of comparison instruments by the National Standards Laboratory which has already calibrated certain items. Other items have been calibrated by the Munitions Supply Laboratories. A National Bureau of Standards electric hygrometer has been constructed and is being calibrated with alternating current over prolonged periods. The readings appear to be reasonably constant after aging is complete. If satisfactory, this instrument will be fitted to air-conditioned cabinets for laboratory use.

(ii) *Physical Properties of Wood.*—Density and shrinkage studies have been continued and several Australian and New Guinea timbers are at present under investigation. True density determinations have been completed on specimens of coco nut palm wood. The results were fairly closely grouped and were very similar in value to those obtained using the wood of conifers and dicotyledons. In other investigations the shrinkage of reaction wood has been compared with that of normal wood from the same tree. The investigation of the production and properties of compressed wood has now been restarted. The determination of the physical properties of certain building boards has been undertaken and certain shrinkage, adsorption, and capillarity measurements have been carried out. These experiments are still in progress and additional conditioning cabinets are being constructed in order to accelerate them.

Work on the thermal conductivity of wood has been continued and the variability of the results greatly reduced by refinements in technique. The tests are now being carried out in a small temperature-conditioned cabinet (± 0.1° C.), and in order to ensure uniform heating the wire grid heaters have been replaced by strip heaters of thin brass covering almost the whole area of the blocks. Improvements have also been made in the method of measuring temperature.

This has resulted in a marked decrease in the variations among repeated measurements on the same specimen.

(iii) *Studies on Creep.*—Further tests on creep in initially green beams have been carried out during the year. Thirty-six beams, excluding controls, were subjected to test. Six have already failed, fourteen have been under loads giving extreme fibre stresses of 2,000 or 4,000 lb./sq. in., eleven have been unloaded and recovery observed, five have been subjected to alternate periods of loading and unloading. Four of the loaded beams have been observed for change in elastic modulus, some by load increments of short duration and some by measuring the period of vibration. Certain of the beams have been under load for approximately one year. All which failed, with one exception, were loaded to an extreme fibre stress of 4,000 lb./sq. in. These failed at from one week to six months from the date of loading. In beams stressed to 2,000 lb./sq. in. the deflection increased five-fold in one year and in beams stressed to 4,000 lb./sq. in. even more. Indications that the elastic modulus is unaltered by prolonged loading are now fairly conclusive. The effect of temperature on the rate of increase of deflection is apparently very marked, as the deflection increases for beams set up in the open many times more rapidly in the day-time than it does at night. The work up to the present on the unloaded beams undergoing recovery suggests that the increase in deflection due to elastic after-effect and that due to plastic flow for beams subjected to an extreme fibre stress of 2,000-4,000 lb./sq. in. for about six months, are approximately equal.

(iv) *Electrical Strain Gauges.*—An attempt has been made to standardize the methods of gauge manufacture and to improve the details of technique at the various stages of the manufacturing process. The glues being used are cellulose nitrate and cellulose acetate dissolved in ethyl acetate. The drying of the glue has been studied and it was found possible to speed up the drying greatly by raising the temperature to 60° C. The use of a current through the gauge for this purpose is now being investigated, overseas experience suggesting that this method will be satisfactory. The effect of change in glue composition is also being studied with a view to ascertaining the degree of constancy in this factor necessary in gauge manufacture.

An improved method of manufacture has been developed for ¼ in. gauges. Methods which involve the winding of a plane wire grid, the end loops of which are located by needle points, have been discarded in favour of a method in which the wire is wound on a paper cylinder which is subsequently pressed flat. Greatly improved results have been obtained with this method. It would appear on present indications that by using 1 mil wire of American manufacture a variation not greater than ± 2 per cent. in gauge factor can be maintained. Gauges of this length made by the Baldwin Locomotive Works in America have a gauge factor stated to be within these limits. An experimental model of a winding machine has been built, and it appears that with minor modifications to maintain greater constancy in the pitch of winding, it will be satisfactory. This will greatly decrease the strain on the operator in manufacturing these small gauges and will increase the uniformity of the product. Attempts have been made to evolve a satisfactory technique for the removal, for re-use, of one-inch gauges after test. There appears to be no difficulty in the manufacture of a rosette consisting of quarter-inch gauges for work on stress concentrations, a satisfactory technique of manufacture having been developed.

It was found during the year that a cupro-nickel wire of American manufacture yielded gauges of much more uniform sensitivity than an English wire of the same type. The American wire contains a small percentage of manganese which may account for its superiority for strain gauge manufacture.

It has been realized that a D.C. bridge is the most suitable device for measuring the small changes in resistance due to strain but on account of the difficulty in obtaining a stable, robust but sensitive detector, an A.C. method has been adopted. Some attempt has been made to develop a suitable pseudo D.C. amplifier but this was not found to be satisfactory. Since the use of 50-cycle alternating current permitted interference from adjacent apparatus to affect the balance point, a 1,000 cycle A.C. bridge with electron ray tube detector has been adopted. This has proved quite satisfactory for calibration purposes, but on account of the undesirability of a separate means of obtaining a reactive balance, a discriminator has been developed to replace the electron ray tube detector for general use. A 1,000 cycle A.C. bridge using an electron ray tube detector has now been built into a permanent unit for use in the calibration of electrical strain gauges in the laboratory.

Work on a 48-channel unit for general use in the Timber Mechanics Laboratory has been commenced. In this equipment, uniselector switches are used for switching the detector circuit. The discriminator mentioned above is used as the detector in this apparatus, the indication being obtained on a milliammeter.

(v) *Battery Separators.*—Owing to the scarcity of Port Orford cedar, Douglas fir of the required quality, hoop pine (*Araucaria cunninghamii* Ait.), and Queensland kauri (*Agathis palmerstoni* F.v.M.), it has become necessary to search for suitable substitute timbers for use in battery separator manufacture. A consignment of klinki pine (*Araucaria klinkii* Lauterb.), from New Guinea, negrohead beech (*Nothofagus moorei* Maid.) from New South Wales, and a number of Queensland rain forest species have been obtained for test. These have been sliced and grooved and scout tests have already been carried out on negrohead beech. The development of methods for the removal of resins and other deleterious substances from klinki pine and negrohead beech has been commenced. Several hardwoods have already been tested for resistance and softening in acid, and some of them have been eliminated as separator timbers without further test. Tests have also been carried out to assess the possibility of reducing the strength of sodium hydroxide solution used for treatment or of its replacement by other substances.

(vi) *Dielectric Heating and Electrical Properties of Wood.*—Work on this project has now been commenced. A report on recent literature on the subject has been prepared as well as a working plan covering the initial stages of the work. Material is at present being obtained. The question of the measurement of the power absorbed by the test specimen has been considered and a trial method decided on.

5. *Timber Mechanics.*—(i) *Design of Containers.*—Considerable assistance has been given to various State and Commonwealth departments and private firms in packaging problems of various sorts. Potato crates, gelignite boxes, drums for the transport of liquids, cases for export of cordial, boxes for electrical cable, and cartons of corrugated paper and fibre board for shoe cleaner in tubes, show the range and variety of the containers which have been tested and investigated. Usually recommendations have been made for improvements in design. A box to house a set of chemistry apparatus was designed for use at the Mildura branch of the University of Melbourne.

(ii) *Standard Tests.*—From the data available in the laboratory on the physical and mechanical properties of Australian species, an abstract of results derived from at least five individual tests and a list of species of approximate order of hardness have been prepared. These not only make the

information available for use but also show the gaps which exist and thus enable further work to be planned to the best advantage. From the abstract, too, a tentative strength grouping of a large number of species has been made. Strength grouping is itself under review and the relationships connecting density and the various strength properties which have been available for United States species are being investigated for Empire timbers and for Australian eucalypts, as are also correlations between bending strength and the other mechanical properties used in structural design.

Some progress has been made with the reporting of pre-war standard testing of several species, and this work will be continued as the availability of staff permits. Because it is expected that the milling of foothill species will increase, standard tests have been carried out on green silvertop ash (*E. sieberiana* F.v.M.) drawn from two areas in Victoria and one in Tasmania. Material from New South Wales will also be included in the investigation. Some logs of white stringy-bark (*E. eugenioides* Sieb.) and brown stringybark (*E. capitellata* Sm.) have also been tested.

(iii) *Silvicultural Treatment and Strength.*—This project, inherently of considerable importance, which was upset by the war, has as its objects the determination of the effects of rapid growth and of age on the properties of wood and the determination of the properties of thinnings of merchantable size. Although it is recognized that the work will virtually have to be restarted, the testing of material which was in the laboratory has been completed and the results will be examined. Analysis of the data for black-butt (*E. pilularis* Sm.) has not disclosed any significant correlations between the various strength properties and silvicultural treatment, nor between strength and crown type. It is considered, however, that the test specimens, which were of 2 in. by 1 in. section, should be restricted if possible to that portion of the cross section whose properties it is desired to investigate. Accordingly, an examination has been made of the effect of building up test specimens by gluing together laminations, which, in a silvicultural project, would be obtained by tangential sawing in the particular material being investigated. Dry hoop pine was used and a comparison was made between solid and laminated specimens in static bending, compression parallel to the grain, Izod, and toughness. It was found that laminating had no significant effect on any of the properties examined. The problem of gluing green material will need to be investigated.

(iv) *Fundamental Studies of Properties of Wood and Investigations of Tests.*—Several studies have been continued during the year, notably those concerning the effect of moisture content on the compressive strength and impact bending strengths of various species, and also the effect of rate of loading on compressive strength. The variation of the impact bending strengths with moisture contents between 0 and 20 per cent. is particularly interesting, as it does not seem to have been fully investigated elsewhere and is different from what has been generally supposed. Instead of an increase in strength with decreasing moisture content below the intersection point, the impact strengths frequently have a minimum value in the vicinity of the equilibrium moisture content. As it has been proposed that an investiagtion should be undertaken of the effect of repeated loading on the strength of wood, a survey of the literature was made and certain conclusions drawn as to the type of equipment and specimen which should be used.

A low-capacity Izod machine which should be of particular value in testing small specimens such as will arise from silvicultural material has been designed. A ball-drop impact testing machine was designed and made during the year. It will be used for furthering impact investigations and also for an investigation of hardness. Some tests were carried out on several species in Izod machines of different capacities. With three species a rise in Izod value with increasing machine capacity was observed, but with mountain ash the reverse was noted.

A detailed study of the torsion test which was devised during the war was started. The effects of varying diameter and length of parallel portion of the specimen were investigated; the indications are that neither has any significant effect on the stresses and modulus of rigidity, but confirmation will be sought using other species. Calibration of the testing apparatus and strain gauge has also been undertaken preliminary results indicating that the method of test is entirely satisfactory. Torsion, as such, is a relatively unimportant property of timber, but the test is regarded as important because of its relationship o shear which is an important property at present evaluated by an unsatisfactory test.

Another important property of timber is its strength in compression perpendicular to the grain, for the measurement of which different methods are employed in Great Britain and in the United States. For some time both tests have been used in this laboratory. A review of the literature showed that there were many uncertainties about the test. Consequently, several experiments have been designed for the investigation of it. The first, testing for which has been completed, used green silvertop ash and included four variables. This will be repeated on other species and on dry material and further experiments will cover other variables.

(v) *Long-time Loading Tests.*—The long-time tests on connector joints were designed to investigate the behaviour of split ring and shear plate joints erected green and left to stand under a tension load for an indefinite period. The load is applied by means of a bolt and is maintained almost constant, despite the movement in the joint, by means of a spring. Three species are being used, mountain ash (*E. regnans* F.v.M.), yellow stringy-bark (*E. muelleriana* Howitt), and Douglas fir, erected in that order, the last specimens being put under load early in the year. A few specimens of all species have failed during the year, but there seems no connexion between the specimens which have failed and the load they have carried or the detail of the joint. Further, the type of failure has been different from that experienced in practice in that, instead of the legs of the joint splitting from the connector to the end, the legs have turned out and failed transversely at the connector. Accordingly, a few tests have been set up, firstly to try various methods for reducing the leg spread, and secondly to try to produce end splitting. One of the latter tests involved a three-member joint, two members of which were double. The eccentric loading of the middle member, arising from one connector being in each face, caused it to twist and to split, but not down the middle: it split from the side of the connector.

Work preliminary to setting up long-time model column tests has continued during the year. It is proposed to use dry material and green material, half of the latter to be allowed to dry out and the other half to be maintained green by enclosing each specimen in a suitable wrapping. Numerous wrappings for this purpose were tried; the most satisfactory method seems to be the wrapping of each specimen in a rubber sheet, together with occasional spraying of the specimen with water and the use of control specimens to check the moisture content by weighing. Two Douglas fir columns which were set up as prototypes for the project have now been standing under load in the one case for nearly three years and in the other for more than two. Their deflections are still slowly increasing.

(vi) *Flooring.*—Testing of floors of various species has been continued, the work latterly being on standard thickness and 9/16 in. material of black-butt, Sydney blue gum (*E. saligna* Sm.), tallow wood (*E. microcorys* F.v.M.), brush box (*Tristania conferta* R.Br.), and spotted gum (*E. maculata* Hook.) from New South Wales. The investigation has included testing the floor panels under the proof loads of the Building Research Station; generally it appears that the thinner material on joists at 18 in. centres is borderline as regards this specification.

(vii) *Fibre Building Boards.*—A comprehensive working plan for the testing of fibre building boards was prepared. As the maximum loads required for the tests on these boards are very low and not conveniently obtainable on the testing machines in the laboratory, the design and manufacture of a low capacity machine which will be a most useful addition to the equipment of the laboratory has been put in hand.

(viii) *Building Materials.*—Considerable assistance has been given Building Materials Research by carrying out tests on various materials, notably tiles and bricks. Other tests on wall and roof panels have also been performed wherever it seemed desirable to give the assistance.

6. *Timber Seasoning.*—(*i*) *Kiln Drying and Chemical Seasoning.*—Following work planned and initiated in the previous year, the bulk of the laboratory kiln schedule studies on satinay (*Syncarpia hillii* F.M. Bail.) from Queensland, brush box from Queensland and New South Wales has been completed; the results are being analysed and appropriate recommendations will be made after confirmation with three further laboratory runs. Present indications are that the kiln drying of selected material of 2-in. thick brush box is a commercial possibility for certain applications. The extremely variable nature of the species makes difficult the drawing of conclusions of a fully comprehensive nature. Hence the suitability of the drying schedule for a particular end use will require specific consideration. The drying characteristics of satinay have much in common with those of brush box, although, in general, drying distortion is rather less, whereas collapse and checking tend to be rather more severe. Quarter sawing is more important with satinay.

The value of a chemical pre-treatment in reducing the extent of degrade developed during the subsequent seasoning of backsown brush box and satinay, was examined; very promising results were obtained. Sodium chloride, in the form of a saturated solution at ambient temperature, was used as the treating salt for periods up to fifteen days.

Kiln schedule work on silvertop ash, white stringy bark, and brown stringybark has been almost completed; only final runs to confirm the results of the previous experiments remain. The experimental work has shown, however, that backsawn material of all these species is unsatisfactory for kiln drying from the green condition without special pretreatment because of the severity of drying checks, but that considerable promise holds for the practicability of commercially kiln drying quartersawn material of all three species from the green condition. All species were found to be susceptible to collapse, the degree of recovery obtained from reconditioning varying to a considerable degree.

Work on the development of a drying technique for veneers of "ash" type eucalypts, which are becoming of increasing importance to Australian timber economy, was carried out in co-operation with the Veneer and Gluing Section. The results indicate that collapse in these species is the cause of both primary and secondary seasoning difficulties in the form of wrinkling, corrugating, and checking. It is of value to note that a considerable improvement in general quality can be effected by reconditioning, and also that veneers cut on, or near, the quarter by staylog equipment or by slicing, behave very satisfactorily during drying and yield a first-class veneer. At this stage the production of high grade plywood from the "ash" type eucalypts would appear to require a combination of rotary-peeled core stock with sliced veneer for the faces.

(ii) *Kiln Design and Aerodynamics.*—With the object of developing a means for improving the output of seasoning kilns in areas subject to extended periods of poor air-drying (such as are found in many parts of Tasmania), a predrier for sorted timber, which operates on a progressive principle and yet avoids the necessity for the usual periodic movement of timber stacks within the drier, was designed by the Section. Incorporated in the design is a method for utilizing boiler exhaust flue gases as the heating medium. The pre-drier is capable of taking multiple timber charges each 8 feet high and 35 feet long. The specific purpose of the unit is to give economic initial drying, from the green condtion to a moisture content of about 25 to 30 per cent., for hardwoods intended for subsequent kiln drying. The prototype is in course of installation.

On request, plans to cover the construction of timber seasoning kilns, veneer and plywood driers, drying rooms, and conditioning rooms to handle a wide range in capacity, species, and thicknesses, were prepared and supplied to some 40 timber seasoning and plywood producing companies; the wide scope of this service is demonstrated by the fact that, not only was assistance provided to consultants in each of the Australian States, but also to several in New Zealand and England. Some 350 drawings were issued. With the object of improving the supply of seasoned timber for housing purposes, performance tests on a number of commercial kilns were carried out; where necessary appropriate recommendations were made to ensure satisfactory performance. Additional detail drawings of modifications made to the earlier design of the cross-shaft kiln, to permit more economic and rapid construction, were prepared.

(iii) *Building Materials.*—Work designed to accelerate the development of low cost building boards and flooring surfaces from freely and economically available organic materials, and the testing of the performance characteristics of these materials, was continued. A fairly comprehensive appreciation of the properties of sawdust-cement has now been obtained, the studies having covered the effects of water-cement ratios, cement-sand-sawdust ratios, timber species, sawdust particle size, sawdust moisture content, neutralizers, and setting accelerators, as well as the extent of movement resulting from drying shrinkage and change in equilibrium moisture content. As a result of these investigations it is now possible to choose compositions, using suitably graded and dried sawdusts, that will give a reliable product. The data developed have been freely availed of by constructional authorities, and several relatively large areas of sawdust-cement have now been laid. Results in service appear to be satisfactory.

Additional experimental work on woodwool-cement building slabs and panels, for use as either interior partition walls or exterior sheathing over a timber frame, was carried out. A number of slabs was manufactured in the laboratory for experimental purposes; an accelerated service test, comprising a temperature-humidity cycling test, was carried out on a jointed panel rendered for external use. Investigation of the effects of woodwool-cement ratios, forming pressures, setting methods, and type of woodwool, on the weathering and physical characteristics of the product, is planned. In this connexion, a large scale exposure test of various constructional methods and finishes is being

prepared in collaboration with the Building Materials Research Section. Several manufacturers have commenced production of woodwool-cement boards, and at least one has now achieved standardized production.

An examination of the value of seaweed, as the bulk material in the production of building slabs, was also commenced: portland cement was used as the bonding agent. A number of test panels was prepared using several types of eel grass (*Zostera* sp.) from Victorian beaches, but satisfactory boards were not obtained because of the low fibre strength of this particular marine grass. Tests of a more fibrous type of seaweed (*Posidonia* sp.) from South Australia, which has relatively high strength properties, were also made, but satisfactory bond was not achieved because of the particularly smooth surface of the fibre. As yet, a seaweed with the requisite properties of good fibre strength, good bonding characteristics, and good setting qualities in an untreated state, has not been found. The value of eel grass as a diluent for woodwool is being examined.

An examination of the possibilities of developng a sawdust-synthetic resin building board has also commenced, and laboratory equipment is being developed. The principal variables to be examined are species, moisture content, particle size, pressure, temperature, resin type, and resin concentration.

On behalf of a fibrous plaster board manufacturer, an electrically heated plaster board drier was designed. The plant is operating satisfactorily and additional installations are contemplated.

(iv) *Sawmill Studies.*—Of recent years the Australian sawmilling industry has become increasingly aware that its industral and economic development is considerably handicapped by the absence of basic data covering existing practice. It is recognized that a proper analysis of factors affecting production would permit a systematic examination of the needs of the industry to be made, this later becoming manifest in the establishment of sawmills designed on a truly functional basis and operating at greatly increased efficiency. As the understanding of this work is, in general, certainly beyond the capacity of the industry itself, it has approached the Division for guidance. As a result, in co-operation with the Queensland Sub-Department of Forestry and the Queensland Timber Stabilization Board, a study of the milling of cypress pine was completed in Queensland; and, in Victoria, in co-operation with Victorian Sawmillers' Association a study of the milling of "ash" type eucalypts was undertaken. From the studies so far completed on the mills handling the "ash" eucalypts, a considerable amount of information was obtained covering mill performances; namely the inter-relationship of production rates and sawn recovery, and their effect on manufacturing margin; the effect of size of sawn product on production rates and recovery; the allocation of total mill time with respect to operational and non-operational (non-productive) time; the reasons for lost production time; and the relation between sawn output, and the quantity of sawdust and waste wood produced in the conversion of log volume. An interim report on this work was written. The work done on mills operating on cypress pine, a final report on which was issued, covers the effect of girth class on production rates, percentage recovery, and sizes sawn in this species. The results of a time study carried out concurrently with the production study also indicate the relative proportions of operational (production) time and non-operational time, and the reasons for the latter.

A minor study to determine the relationship between depth of cut and feed rate for two bandsaws cutting fire-killed mountain ash was carried out.

(v) *Miscellaneous Seasoning Investigations.*—A wide range of minor miscellaneous enquiries and investigations was handled during the year, mostly on behalf of industrial consultants for whom no alternative source of enquiry or investigation was available. Subjects, on which limited amounts of work or investigation were carried out, included the drying of lawyer cane, spaghetti, clothes pegs, veneers, timber for smoking pipes, and furs; drying costs; collapse and reconditioning; moisture meters; temperature control equipment; vacuum kilns; the burning of wood waste as fuel; timber handling; tool handles; sub-floor heating; wood-dust extraction, &c.,

(vi) *Correspondence Courses.* — The greatly increased activity in the correspondence courses in timber seasoning as reported for the first post-war year was maintained during the past twelve months. An additional 51 students were enrolled.

7. *Timber Preservation.*—(i) *Field Tests.*—The field testing of preservatives and of various methods of treatment represent an important aspect of wood preservation work. The majority of these tests, which were installed in pre-war years, have now reached the stage where results are apparent and are of important and immediate application. Inspection of field tests many of which were to some extent neglected during the war, has therefore constituted an important phase of the year's work and is being undertaken by senior officers with the object of inviting the presence of technical representatives of Government Departments and timber-using authorities and of discussing the application of the results to their particular problems. This policy has secured very desirable publicity and has met with an excellent response.

During the year, all field tests in New South Wales were inspected and reports circulated widely. Pole and fence post tests at Wyong, Clarencetown, and Mount Jamberoo were inspected in co-operation with officers of the New South Wales Forestry Commission and in the presence of many visitors including representatives from Victoria and Queensland. Results have demonstrated the value of four different methods of pole preservation and have shown that low durability timbers effectively treated should still be in almost perfect condition after 11-12 years service. Inspections were also made of small specimen tests at Canberra and of rail sleeper tests in Victoria. The latter tests which include many lower durability timbers which must be used in the immediate future to augment sleeper supplies in Victoria, are yielding important results and demonstrate the value of preservative oils in reducing both decay and mechanical deterioration.

(ii) *The Preservative Treatment of Eucalypt Truewood.*—The problem of the preservative treatment of the truewood of eucalypts of lower durability, particularly for rail sleepers, is an urgent one. The supply of naturally durable timbers is now insufficient to meet normal maintenance sleeper requirements in Victoria, and a similar position is developing in some other States. Unfortunately eucalypt truewood is very refractory to penetration with preservatives, and conventional methods as used abroad for softwood timbers cannot be applied with success. Two possible methods of treatment, however, are under investigation and the present position may be summarized as follows.

(*a*) *Treatment at high pressure.*—From preliminary tests satisfactory pentration of the truewood of many eucalypt timbers was obtained at pressures of approximately 1,000 lb. per sq. in. using both oil- and water-soluble preservatives. This very promising result was obtained with small specimens and cannot be accepted as a solution to the problem of treating rail sleepers until repeated with speciments of larger size. It is also necessary to demonstrate the practicability of the method on an economic basis. During the current year, work has proceeded on the above aspects and final tests have now commenced. Although the project has been accorded urgent status, delays have been unavoidable

as it has been necessary to collect suitable material representing a number of trees from each of the principal eucalypts in the lower durability classes. It has been further necessary to season this material before final tests can be made. Interim results have so far confirmed the initial promise of the method, and during the coming year it is planned to instal a high-pressure cylinder of sufficient capacity to treat full sized rail sleepers for service tests. In this work, water-soluble preservatives have now been discarded in favour of creosote oil in view of the increasing evidence that suitable oil preservatives possess the very necessary attribute of retarding mechanical failure in sleepers as well as conferring lasting protection against decay.

(*b*) *Treatment by diffusion.*—This investigation was commenced with the object of developing a diffusion treatment for eucalypt truewood as an alternative to pressure methods. A fundamental study of the diffusion process was undertaken and has been completed to a stage where it is now apparent that manipulation of treatment variables (temperature, duration of treatment, type of chemical, solution concentration, and pH) will not economically produce a result greatly superior to the already thoroughly tested "fluarizing process" which has been in use in Western Australia for many years. As extensive field tests of sleepers treated by this process have not given highly satisfactory results, diffusion treatments are now considered to have a limited prospect of success for eucalypt rail sleepers.

Although the original object of the above work has now proved unattainable, fundamental diffusion studies have continued in connexion with other applications. In particular an examination has been made of the relative diffusion rates of boric acid and other salts through the sapwood and truewood of five of the principal Queensland timbers now being treated commercially with boric acid to prevent Lyctus borer attack. This study has shown that diffusion rate in the radial direction is significantly faster (two or three tmes) than that in the tangential direction and has explained the practical difficulties being experienced in the treatment of quartersawn boards. It has also demonstrated that the diffusion rate of boric acid is faster than that of sodium fluoride and that, from this aspect, no change in the preservative chemical used is desirable.

During the above work it became apparent that a study of diffusion of electrolytes into timber offers a possible method of approaching certain fundamental aspects of the physical chemistry of wood. Work is therefore being continued with this additional objective.

(iii) *Lyctus Investigations.*—A considerable amount of work has been undertaken on the Lyctus borer problem principally from the aspect of examining simpler methods of preventing attack in plywood made from susceptible timbers. In addition a survey has been completed with the object of classifying Australian and New Guinea timbers according to susceptibility to Lyctus damage. Progress in these investigations may be summarized as follows.

(*a*) *Prevention of Lyctus attack in plywood by addition of toxic chemicals to the glue line.*—In this investigation 1,440 test plywood panels, representing three timbers and two veneer thicknesses, were prepared by bonding with casein and urea glues to which various toxic chemicals had been added. The test was set up in 40 insect-proof cages and inoculated with several thousand Lyctus beetles. Results of this work will not be available until next summer when the number of beetles emerging from treated and untreated panels will determine the relative success of the various treatments. The plywood industry has shown great interest in these tests. If the method is successful it will prove of immediate value in the utilization of the Lyctus-susceptible plywood timbers of Queensland and New South Wales.

(*b*) *Modification of the existing boric acid process for treatment of Lyctus-susceptible veneer.*—An investigation is now proceeding to determine whether the present commercial boric acid process, which involves stripping the veneer in finger crates and immersing in a tank of heated boric acid solution, can be simplified to a process requiring only momentary immersion in cold boric acid solution followed by block-stacking of the veneer to permit diffusion. For this test freshly peeled green veneer from six timber species was obtained through the co-operation of the Queensland and New South Wales Forest Services and sent by air to Melbourne for immediate treatment. Treated veneer was bonded into 3-ply sheets and inoculated with paired Lyctus beetles in 312 small insect-proof cages. Results should be available next year. For both the above tests, mass breeding of Lyctus beetles was necessary and was achieved successfully. During the period of highest emergence, daily collections of more than 200 beetles were obtained.

(iv) *The Toxicity of Metallic Naphthenate Preservatives.*—Metallic naphthenates have continued to gain favour as wood preservatives in Australia, but have performed somewhat erratically in field tests conducted by the Division. Work has therefore been commenced to examine the chemical composition, toxicity, and permanence of metallic naphthenates with respect to the origin of the naphthenic crudes. The final object of this work is to establish a specification for metallic naphthenates for wood preservation. Development of satisfactory fractionating methods and general technique of study is now proceeding and is being followed by preliminary tests to correlate toxicity and permanence with distillation range and acid number.

(v) *The Development and Test of External Coatings for Woodstave Pipe in Western Australia.*—Following the inspection last year of woodstave pipe in the Goldfield's water supply system, Western Australia, the assistance of the Division was sought in the development of suitable protective coatings. This work has progressed to the stage where solar exposure tests of 43 coatings are in progress. Formulae for priming and main coats were based mainly on horizontal tar, horizontal and vertical pitch, air-blown and steam-distilled bitumens, wool grease, and lanoline. Fillers included asbestos, mica, limestone, and cement. A preservative (creosote oil or pentachlorphenol) was incorporated in the priming coats. The Munitions Supply Laboratories are also co-operating in this work in the development of a final light reflecting coat to be used over the tar-base paint on the upper north quadrant of the pipe where the solar effect is intense.

(vi) *General Survey Work.*—The two surveys mentioned briefly in the previous report are still continuing. In connexion with marine borer attack in harbour installations, data have now been obtained from the majority of Australian ports and will be summarized shortly. The survey to determine causes of service failure of pole crossarms throughout Australia has reached the stage where inspection of collected crossarms in all States will commence almost immediately. Printed cards have been prepared for recording the service history of each arm collected and 5,000 have been distributed to the various depots where collection is being made. It is hoped that the results of this survey will assist materially in planning the most effective utilization and treatment of lower durability timbers which of necessity are now being accepted for crossarms.

(vii) *Timber Mycology.*—Major work in this subject has been the testing of methods for determining durability of timbers to decay by accelerated laboratory technique. Using various methods, approximately 3,000 test blocks have been inoculated with pure

cultures of wood-destroying fungi to standardize and improve testing technique for planned future projects. Interim results indicate that further preliminary work will be necessary before laboratory methods can be used accurately to compare the natural durability of timbers and before such methods for determining the effect of silvicultural treatments on durability of plantation grown and treated forest timber, may be employed.

8. *Veneer and Gluing.*—(i) *Veneer Production.*—During the period under review the following species were peeled, with a view to overcoming technical difficulties associated with the conversion from the log form into veneer: alpine ash, messmate stringybark (*E. obliqua* L'Herit.), mountain ash, and silvertop ash. The main difficulty with this group of eucalypts was to dry the veneers without degrade due to collapse. Several methods of solving this problem were tried in co-operation with the Seasoning Section, the most satisfactory being to depart from the normal method of rotary cutting, so that the veneers were sliced at a large angle to the growth rings. Economically, this has the disadvantage that large sheets of veneer are not produced consistently, but this may be more than compensated for by the increased recovery. Another possible source of plywood is New Guinea, and experiments have been carried out on the peeling and drying properties of klinki pine with very satisfactory results. Other softwood species which are now being investigated for plywood purposes include slash pine (*Pinus caribaea* Morelet) and loblolly pine (*Pinus taeda L.*) from Queensland. These are the southern pines of the United States, and the Queensland Forest Service is growing certain plots with the object of producing the maximum volume of peeler logs; it is therefore necessary to have full data on their peeling, drying, and gluing characteristics before the trees reach maturity in order to determine the correct silvicultural treatment.

Some experimental studies have been made of the best heating schedules for veneer logs before peeling, they have involved the application of the theory of heat transmission through wood to Australian species. By suitably varying the temperature of the heating medium, it was found possible to obtain a very small temperature gradient through the log.

(ii) *Gluing Investigations.*—Systematic gluing tests were carried out on the following species with a range of adhesives: hoop pine, radiata pine, mountain ash, yellow walnut (*Beilschmiedia bancroftii* C. T. White), northern silver ash (*Flindersia pubescens* F. M. Bail.), southern silver ash (*Flindersia schottiana* F.v.M.), rose alder (*Ackama quadrivalvis* C. T. White), myrtle beech (*Nothofagus cunninghamii* Oerst.), bollywood (*Litsea reticulata* Benth.), leatherwood (*Eucryphia billardieri* Spach.), loblolly pine, coachwood (*Ceratopetalum apetalum* D. Don), and alpine ash. Minor investigations of the gluing characteristics of several other species were made. The effects of various factors within the species, including locality of growth, density, and angle of gluing surface to growth rings, were studied. Some attention has been paid to methods of bonding materials differing from wood in physical and chemical properties. Metals, fibre-boards, asbestos-cement, ceramics, and cellulose plastics have been glued either to themselves or to wood. In most cases the problem has been not merely to obtain satisfactory adhesion, but to do so under prescribed conditions, not necessarily the optimum. A new project aiming to investigate the nature of adhesion has been put in hand, and initial experiments have approached the problem from the chemical standpoint. Although as yet inconclusive, preliminary work indicates that the role of the hydroxyl groups in the wood substance may not be of major importance.

(iii) *Development and Testing of Adhesives.*—Experiments were completed on the use, in the preparation of plywood adhesives, of potato starch produced in Australia. Strongest joints were obtained with mixes containing relatively low proportions of alkali and of water, but the viscosity of these glues is somewhat higher than that of adhesives commonly used in the plywood industry. It has been reported by overseas workers that soya bean glues are more suitable for gluing softwoods than hardwoods, and an investigation is being made to determine whether similar results are obtained with Australian species, and, if so, to find the cause. A necessary preliminary step was the development of a satisfactory basic formula. It appears that good bonds can be made with some Australian hardwoods, at least although in general the results were somewhat inferior to those for the softwoods tested.

Preliminary work has been done in an investigation aiming to explore the possibilities of various lignins (by-products of the pulp and paper industry) as extenders for synthetic resin adhesives. Simple extension of the prepared resins with lignin did not yield good results, but there were indications that incorporation of the lignin as a step in the synthesis had possibilities. To obtain some familiarity with the phenol-formaldehyde reaction, some liquid resins have been prepared, and a subsidiary experiment involved the preparation of cold-setting phenolic resins and the determination of the minimum hydrogen ion concentration compatible with a reasonably short setting time. A review of the literature on lignin and resin has been made and equipment has been obtained to carry out experiments on a systematic scale.

(iv) *Durability of Plywood.*—Plywood panels made up under a range of conditions from various species and adhesives, and in some cases treated with protective coatings, were exposed to the weather with a view to determining how deterioration may be minimized in external use. Frequent examinations have been made, particular attention being paid to the incidence of face checking and of delamination at the glue line. The relative efficacy of the various treatments has been determined, and it has been shown that the thickness of the veneers, the method of gluing, and the moisture content at assembly exercise significant effects upon the degree of face checking. As regards the durability of different types of glue, it appeared evident that cold-setting urea-formaldehyde resins could not be depended upon for exterior use unless well protected. Superior durability was shown by hot-setting adhesives. Accelerated weathering tests are being carried out at present in a weatherometer which has been completed recently.

(v) *Deterioration of Glue Lines.*—An investigation has commenced into biological factors influencing the deterioration of protein glues. Initially this experiment aims to compare the relative effects of hydrolysis and of micro-organisms in the breakdown of adhesives by determining the strength of sterile and non-sterile glues at various periods after mixing.

(vi) *Plastic Deformation of Plywood.*—Work has been carried out on the plastic deformation of plywood subjected to compressive forces acting normal to the face of the panel. Initial experiments were designed to investigate the effect of temperature upon the residual deformation of panels pressed for a fixed time under varying loads. It was found that, for oven-dry material, the load at which appreciable residual deformation took place declined rapidly with rising temperature from 120° to 160° C., and was small above 160° C. The virtual disappearance of a yield value near this temperature appeared to represent quite a fundamental change in plastic behaviour. Elastic after-effects were later observed, and for a pressing time

of five minutes elastic after-effect tended to a finite value which was usually about half of the corresponding total residual deformation at a pressing temperature of 120° C., a proportion which declined to one-seventh at 200 °C. The influence of elastic after-effect was such as not to alter radically the effect of temperature upon yield-value.

Microscopic studies on the same specimens, carried out in co-operation with the Section of Wood Structure, showed that the radial pressure required to produce fracture of the cell wall declined with temperature, the effect being linear over the range examined. On the temperature-pressure diagram it was found possible to define three main zones of deformation; those of elasticity, flow, and fracture. The zone of flow was divisible further into areas of plasto-elasticity and visco-elasticity. There appeared to be some evidence that the location of flow in the wood tissue was largely in the cell wall. Generally it was concluded that rheological studies may contribute to the knowledge of the structure of the cell wall and that short loading times and elevated temperatures could be used with advantage to clarify the theory of flow in wood, particularly as it affects such applications as the manufacture of plywood and densified wood and of plastics containing wood waste. The investigation was extended to determine the effects upon residual deformation, yield value, and fracture stress of other variables. Moisture content, time of loading, and direction of loading relative to growth rings, have been studied and species and density are now receiving attention. Solid wood has also been compared with plywood as regards its suitability for basic studies.

9. *Utilization.*—(i) *General.*—Requests by industry for assistance in the solving of a wide range of problems associated with the setting up of new processes and the operation of established industries, proved heavy throughout the year. This effect, no doubt, has been occasioned partly by a reconversion of the activities of many of the timber-using industries to civilian production, and partly by the need of many plants not only to find substitutes for previously imported timbers, and the means of compensating for shortages in Australian species, but also to develop improved production methods to give more complete and more economic utilization than earlier considered necessary. The importance of this work to the timber industry and dependent enterprises (including those of housing, furniture manufacturing, agricultural implement making, spinning, weaving, packaging, and crating) is demonstrated by the very considerable use made of the facilities and experience available within the Division by private and Governmental and semi-Governmental authorities. Representation was provided by the Section at conferences on the standardization of timber for use in building construction, on sawmilling and utilization, and on the supply of timber for house construction. To permit acceleration of the industrial developments in the paper industry, the services of the Officer-in-Charge of the Section were made available to the industry for a period of eight months.

(ii) *Timber Uses.*—Notes on the properties and uses of a wide number of species were prepared for industrial contacts. Descriptive summaries covering the habit, distribution, physical and mechanical properties, durability, seasoning and gluing characteristics, uses, and availability of certain other species were prepared for distribution.

Specific inquiries from industry on which advice was given included the suitability of various species for butchers' blocks, fire plugs, special medical equipment, water cooling towers, wheelwright work, pattern making, condenser tube plugs, electrical contact-breaker arms, shuttles, handles for mallets, floor-sanding machines, tool handles, textile rollers, bakers' peels, printers' blocks, plasterers' floats, shingles, kerbing, boat building, butter boxes, hat blocks, automobile bodies, pegs, shoe heels, smokers' pipes, stacking forms, vats, hammer beams for forging machines, the spring arms of fruit grading machines, beehives, violin bows, crossarms, and sporting goods.

(iii) *Cases.*—A number of inquiries covering the suitability of white birch (*Schizomeria ovata* D. Don), jarrah (*Eucalyptus marginata* Sm.), karri (*Eucalyptus diversicolor* F.v.M.), and radiata pine as butter-box timbers were handled. Data were prepared on the suitability of several imported softwoods for case timbers, on possible supplies of veneer suitable for packaging, on species suitable for egg crate manufacture, and on the availability of equipment for jointing box corners. A preliminary discussion was held with the Victorian Department of Agriculture to examine the value of a conference between fruit growers and case-timber millers and suppliers, on the question of seasonal requirements of case material. Work designed to test the suitability of a number of Australian species for slicing as case material was taken in hand.

(iv) *Standards.*—Of considerable importance to the Australian timber-using industries is the development of Australian Standards and Codes of Practice covering the production and usage of timber products. Over the past few years the work of the Section in this field had to be considerably curtailed because of the more immediate demands of other problems. The importance of the standards work was not forgotten, however, and a resumption of the earlier activity of the Section in this direction is now in progress. To this end an attempt has been made to facilitate the development of the further work of the Standards Association of Australia Timber Sectional Committee. At this stage an examination of deferred draft standards and past approved specifications, covering timber grades and the quality of milled products, is in hand. Information covering the standard profiles for flooring and weatherboards adopted in Tasmania and Victoria was prepared at the request of industrial contacts. Draft specifications for milled products of radiata pine were submitted for the consideration of the Victorian Timber Industry Council. The normal secretarial work of the Timber Sectional Committee of the Standards Association of Australia was maintained.

(v) *Manufacturing Processes.*—Requests from industry for assistance in this field also remained active throughout the year; in a number of cases some experimental work was necessary before suitable advice could be given. With the co-operation of a company manufacturing equipment for high-frequency heating, attention was given to the technique of preparing laminated hat blocks from several Australian species using a phenol-formaldehyde adhesive and dielectric heating, several were distributed for service trials. Active interest was also shown in the manufacture of wood flour, and advice was given with regard to species availability, production method, production costs, and uses. Data were also supplied on the following subjects: vat construction to hold 15 per cent. HCl at a temperature of 140° F., a method to provide for the simultaneous bending and fitting of handles to the curved sockets of shovels by the use of hot oil; a method to give satisfactory staining of tool handles with the use of 1 per cent. ferrous sulphate solution; manufacturing methods suitable for the production of venetian blind slats from Australian species; the destructive distillation of wood; the bleaching of tempered hardboard for building purposes; equipment for the extraction of resin from wood; pressure requirements for the manufacture of 11-inch diameter discs from a tempered hardboard for use in electric meters; the machining of stock for edge gluing; the

use of densified wood as a component of fruit grading machines, and for band-saw guides; rumbling technique; the manufacture of skis and fishing rods.

(vi) *Waste Utilization.*—An Australia-wide survey of the saw-dust production of saw-millers and wood-using industries (box and case manufacturers, joinery manufacturers, and furniture manufacturers) was made during the year, and an attempt made to ascertain availability of supplies. Analysis of the data obtained is giving a valuable appreciation of the quantity and range of supplies from various potential key centres of saw-dust utilization.

(vii) *Miscellaneous.*—An examination of the effect of sub-floor heating on the serviceability of a wooden test floor has been carried out in co-operation with the Seasoning Section using low wattage tubular electric heaters beneath the wood floor but between the floor joists. An investigation was commenced for a method of temporarily sealing the flooring of a new type of pre-fabricated house, so that floors laid prior to the erection of roofing materials would be suitably weather-proofed. The procurement of timber test material for the various sections of the Division was maintained.

10. *Publications.*—The following papers were published during the year:—

Brims, B. (1947).—Molecular weight distribution curves of various holocellulose fractions. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 276-88.

Cooper, K. L. (1946).—Timber research: extract of paper presented at Adelaide meeting of A.N.Z.A.A.S., August, 1946. *Aust. Timber J.* 12 (11): 630, 633, 635-6, 639, 641, 668.

Dadswell, H. E., and Ingle, H. D. (1947).—Wood anatomy of the Myrtaceae, I. *Trop. Woods* (90): (June 1).

Dadswell, H. E., and Wardrop, A. B. (1946).—Cell wall deformations in wood fibres. *Nature* 158: 174.

Dixon, C. E. (1946).—Container testing and design: laboratory packaging research effects important saving of weight and cost: Packaging organization would benefit Australian industry. *Mfrg. and Manag.* 1 (6): 244-8.

Greenhill, W. L. (1946). — Temperature and moisture contents attained by wooden aircraft in service in Australia. Aust. Coun. Aero., Report ACA-23.

Harris, E. E.* (1946).—Production of alcohol from Australian woods. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 303-10.

Higgins, H. G. (1946).—Note on the assessment of bush fire hazard, with a suggested design for a simple "hazardometer". Ibid. 19: 293-4.

——— (1946). — Critical temperature range in the plastic deformation of plywood. Ibid. 19: 455-62.

Watson, A. J. (1947).—Preparation of a wood sample for chemical analysis. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 289-96.

IX. FOOD PRESERVATION INVESTIGATIONS.

1. *General.* — In the last annual report, a brief account was given of some of the more important changes which had taken place in the scope of food preservation investigations following the end of the war. An additional major project has recently been commenced by the Physics and Transport Section, viz., an investigation of the transport of frozen produce in insulated railway vans. It has also been possible to give more attention to several long-term chemical and biological studies of a fundamental character.

The Division provided lecturers in two special courses of instruction. Under the auspices of the Australian Chemical Institute and the Sydney Technical College a course of lectures and demonstrations was given on the storage of fruits and vegetables. In connexion with the School of Fisheries organized for the Ministry of Post-war Reconstruction, the Division provided lecturers and demonstrators for the section of the course dealing with the handling and preservation of fish.

Several years ago it was realized that some co-ordination of research work in Australia on the storage of fresh fruit and vegetables was desirable. Accordingly, in 1941, a special committee was formed representing the Council, the Department of Commerce and Agriculture, and several State Departments of Agriculture. Owing to the war, its first meeting was delayed until 1946. In future, meetings will probably be held annually and every State Department of Agriculture will be represented. The work of this committee promises to be very useful, as a means (*a*) whereby investigators in the various organizations represented can freely exchange detailed information of work in progress, (*b*) of avoiding unnecessary overlapping of research work, and (*c*) of reviewing major problems in the field, and, where possible, allocating studies of these problems to particular groups of research workers.

It is pleasing to record that two senior research students selected by the Government of India have recently arrived at the Division's Homebush laboratories and have joined the teams of investigators engaged in research work on the storage and processing of fruits and vegetables.

The Council is indebted to Professor N. A. Burges, Botany Department, University of Sydney, for the provision of laboratory accommodation for two research officers working on problems of plant physiology. The close co-operation existing between the staffs of the Botany Department and of the Division's fruit storage section continues to be a source of considerable help and inspiration in the investigations on the storage of fresh fruit.

Close liaison is being maintained with most sections of the food industry through contact with many individual firms and various trade associations. At the request of the Commonwealth Cold Storage Association, the Division undertook the major part of the preparation and writing of a brochure on recommended procedures for the cold storage of a wide range of foodstuffs. Several firms have shown their desire to help the work of the Division by making substantial monetary grants.

2. *Physical Investigations.* — (i) *General.* — The Physics and Transport Section has continued to supervise the maintenance and running of mechanical equipment used for controlling storage conditions and other work in the laboratory. Collaboration with other sections and general advisory work on various problems together with statistical analyses of data have taken up a large part of the investigators' time.

(ii) *Cooling of a Wet Body.* — The calculations referred to in the previous report have been continued. Equipment constructed for the experimental work is being modified to overcome electrical faults.

(iii) *Shipping of Frozen Meat.*—Many of the newer refrigerated ships are cooled by the "jacket" system using forced circulation of air over batteries of brine pipes situated outside the cargo spaces. As the fans cannot be run during loading, some rise of temperature of the cargo may result. Measurements were made on one vessel during the loading of frozen meat in

* U.S. Forest Products Laboratory, Madison, Wisconsin.

north Queensland and Sydney in order to estimate the risks of "dangerous" temperature rises during the loading of frozen cargo. A report has been forwarded to the British Refrigerated Cargo Research Council at whose request the work was carried out.

(iv) *Rail Transport of Frozen Meat.*—Observations made during the work referred to in the previous paragraph indicated that rail transport to the ship was often a weak link in the chain of operations. This problem was studied in two stages:—

(*a*) New South Wales refrigerated rail vans were loaded with ice to obtain data on the rate of pre-cooling and the heat load, the rate of heat leakage in the "steady" state, and the effect of open doors. Measured values were compared with calculated values to see whether extension of the results to other conditions and handling procedures was likely to be reliable.

(*b*) Measurements were continued in a Queensland insulated railway van. Temperatures and ice consumption were measured during pre-cooling, and meat and air temperatures were measured during the transport of frozen meat to a port of loading. The results were analysed in order to estimate the relative importance of incomplete pre-cooling, "normal" heat leakage, and "exposure" during loading and unloading. The performances to be expected from a number of suggested alternative designs for new vans were estimated. Further studies on the transport of frozen produce are being planned.

(v) *Cold-store Survey.*—A survey of representative commercial fruit stores has been undertaken in order to: (*a*) determine the magnitude of the temperature variations in space and time within storage rooms, (*b*) collect evidence on the causes of the variations and possible means of improving uniformity, (*c*) obtain information on the relative humidity in stores, and (*d*) estimate the efficiency of the cooling systems used. Measurements are in progress in one store in New South Wales and three in Victoria.

(vi) *Vapour Pressure of Dried Foods.*—The studies of the relation between vapour pressure and water content of dried egg and dried onion have been continued. Both adsorption and desorption isotherms have been obtained.

(vii) *Colour Measurement and Grading.*—Specification of colour and measurements of colour changes are needed in many branches of the work of the Division. It is desirable to obtain methods which are more precise and more objective than some of those at present in use. The Council's Physics Division has co-operated in the development of this work by designing a photoelectric tricolorimeter which can be adapted for measurements on foodstuffs, and by making available a Hardy recording spectrophotometer for some measurements. A reflectometer using balanced photocells has been designed for use with narrow band light filters.

3. *General Chemistry.*—(i) *Metals in Foods.*—An accurate method for determining iron in canned foods, using ortho-phenanthroline, has now been developed. The investigations included the determination of the redox potential of the iron-dipyridyl and iron-phenanthroline complexes and the instability constant of the ferrous-dipyridyl complex. Three papers were prepared for publication. Investigations on the polarographic determination of copper have been initiated.

(ii) *Tinplate.*—The work on the determination of tin coating weight of tinplate was completed, and a paper was prepared for publication. Preliminary work on the porosity testing of tinplate was completed. Arrangements were made for further tests to be carried out at the International Tin Research Institute, England.

(iii) *Dissolved Oxygen in Orange Juice.* — (with Canning Section).—A paper on the polarometric determination of dissolved oxygen was prepared for publication. The rate of oxygen-consuming reactions in orange juice was found to be negligible below 10° C.

Very complete de-aeration of orange juice (to less than .005 per cent. of dissolved oxygen) was obtained by passing inert gases for 30-45 minutes. Canned orange juice was prepared at 5° C. both with and without de-aeration and samples were stored at 5°, 20° and 30¾ C. for subsequent examination.

(iv) *Polarography.*—Investigations on polarography included the effect of viscosity on polarographic diffusion currents and the development of a more satisfactory type of cell. The operating characteristics of automatic recording polarographs have been studied.

(v) *Lipoid Coating of Apples.*—Further investigations have been carried out on the fatty acids and unsaponifiable matter of the oil fraction. A preliminary separation of fatty acids was made by means of solvents. Separation by formation of succinic half esters or low temperature crystallization of methyl esters was not successful. The unsaponifiable matter was partially separated by means of solvents and distillation *in vacuo*.

The coating material was extracted from samples of Jonathan, Granny Smith, and Sturmer apples with carbon tetrachloride and separated into fractions. The "resinous" fraction from Jonathan apples was harder and had lower saponification and iodine values than the corresponding fraction from the other varieties. The skin of Sturmer apples was found to contain a considerable quantity of white powder which was practically insoluble in carbon tetrachloride. The wax and oil fractions did not differ appreciably in the three varieties.

Changes in the natural coating of Granny Smith apples during storage at 0° C. are being studied. The effect of district and maturity is also being investigated, and significant differences have been obtained. The "resinous" fraction obtained from freshly picked apples differed markedly in properties from the same fraction obtained previously from long-stored apples. About .06 per cent. of lipoid material was obtained from the flesh of Granny Smith apples. In an apple of average size about half the total lipoid material is in the skin.

(vi) *Volatile Products of Apples.*—The production of volatile organic substances by Granny Smith apples was determined over a period of about six weeks at 20° C. The procedure involved absorption of the carbon dioxide of respiration in soda lime and combustion of the volatile organic substances over catalysts at 600° C. The carbon dioxide produced by combustion was absorbed in alkali and determined conductimetrically. The method is not quantitative, as volatile esters were found to be partially absorbed by the soda lime. The production of volatiles by Granny Smith apples was definitely lower than that reported in the literature for other varieties. Volatile production in all samples tended to pass through an initial maximum, then a minimum, and finally a steady increase. These changes occurred more rapidly in later picked fruit. Investigations have been initiated on the absorption of volatile esters from an air stream and their subsequent determination by a colorimetric procedure.

(vii) *Chlorophyll.*—Preliminary work on the determination of chlorophyll in fruits and vegetables has been carried out. The usual colorimetric determination in an acetone extract was found to be subject to interference by other pigments, and it was found desirable to transfer the chlorophyll to ether after the initial extraction.

(viii) *Ascorbic Acid.*—Work on the determination of ascorbic acid included the investigation of "apparent ascorbic acid" in green walnuts. The "apparent ascorbic acid" appears to be confined to the pericarp. Attempts to isolate it have not yet been successful. "Apparent ascorbic acid" was also obtained by heating solutions of sucrose with dilute mineral acid. No conclusive results were obtained on heating fruit and vegetable suspensions. A commercial malted product was examined for "apparent ascorbic acid".

Work is being initiated on the mechanism of the metal catalysed oxidation of ascorbic acid. The effect of various chelating substances on the copper-catalysed oxidation has been studied. The copper-catalysed oxidation was also studied in suspensions of onion tissue. Most of the "protective" effect which inhibits copper catalysis, was associated with the volatile substances of the tissue.

The enzymic oxidation of ascorbic acid was studied in cabbage and apple suspensions. The oxidase of cabbage was found to be mainly in the insoluble portion but was partially soluble in dilute salt solutions. The enzyme was precipitated by saturated ammonium sulphate without loss of activity. Oxidation of ascorbic acid in apple suspensions was very variable and the mechanism appeared to be largely indirect.

The rapid loss of ascorbic acid from silver beet after picking was not found to be associated with wilting. An attempt was made to prepare an ascorbic acid rich concentrate from orange rind by extraction, fermentation, filtration, and evaporation. The ascorbic acid was well retained, but the product was still bitter. Activated carbon removed the bitterness but promoted oxidation of ascorbic acid. Methods proposed by Russian workers failed to reduce the pro-oxidant effect of the carbon.

(ix) *Dehydroascorbic acid.*—Investigations are now in progress on the stability of dehydroascorbic acid, which is obtained by the oxidation of ascorbic acid but retains antiscorbutic activity. The stability was studied at various pH levels (from 0 to 7) over a range of temperatures (0°–100° C.). Maximum stability was found at pH 2-3. The destruction was not affected by the presence of oxygen or cupric ions. Borate appears to accelerate the destruction of dehydroascorbic acid but tends to stabilize the first product of hydrolysis (diketogulonic acid).

4. *Microbiology.*—(i) *Egg Investigations.*—Experiments on the pasteurization of shell eggs have been continued on a considerable scale. The principal aims have been to determine the most suitable conditions of pasteurization for eggs that had been exposed to a wide range of conditions between laying and pasteurization. The effects of pasteurization have been assessed on the basis of freedom from bacterial rotting after storage, and in terms of other internal-quality factors not associated with microbial wastage.

From the aspect of control of rotting, it has been shown that a number of pasteurizing treatments are capable of almost completely eliminating rots when the pasteurization is carried out up to seven days after cleaning. The probability of obtaining complete control of rots is reduced, however, as the potential wastage increases, as the temperature and duration of holding between cleaning and pasteurization are increased, and as the temperature of the pasteurizing water is increased above 145° F. approximately.

Pasteurization, especially at relatively low temperatures, resulted in significantly increased retention of thick white although the effect on yolk quality was generally insignificant. Viscosity of the thin albumen baking quality, and the rate of water loss from stored eggs, were all unaffected by pasteurization. Pasteurization in oil was less effective for the control of rotting than was pasteurizing in water, although oiling resulted in other benefits including reduced evaporation and improved retention of yolk and albumen quality.

Two experimental shipments of shell eggs including pasteurized and oiled treatments were forwarded from South Australia to England where detailed examinations were made by officers of the Food Investigation Board. Under these conditions the pasteurizing treatments effected a substantial reduction in microbial wastage for machine-cleaned eggs, although the effects on other internal quality factors were small.

Some preliminary comparative measurements have been made on the bacteriological quality of egg pulp produced by hand and machine methods of breaking.

(ii) *Clostridium botulinum Investigations.*—Studies of the growth of this organism have been continued, particularly in relation to inhibition by tin and other metals in solution. Some time has been devoted to the development of satisfactory procedures for determining thiol compounds in the media used. Experiments on the destruction of botulinum toxin by heat have been continued, and this aspect of the work is nearing completion.

(iii) *Examination of Canned Foods.*—A manual giving details of methods for the bacteriological examination of canned foods is being prepared for publication. This publication will summarize the rather extensive experience gained by the Division when large numbers of cans were examined during the war years.

(iv) *Heat Resistance of Bacterial Spores.*—The experiments have been continued with the spores of several strains of *Bacillus* and *Clostridium*. In attempting to elucidate the role of starch added to media for detecting surviving spores, special attention was paid to certain strains of *Bacillus* with simple nutritive requirements. The results of these experiments suggest, although they do not prove, that the starch has a direct effect on the germinating spore. This work has been interrupted by the resignation of the investigator.

(v) *Disinfection by Cationic Detergents.*—A study of the anti-bacterial properties of these surface-active compounds was commenced last year. The experiments have been continued with the object of determining the conditions under which these compounds are most active. The susceptibility of eight strains at several pH levels has now been determined for two compounds of this type. While previous workers had claimed that these compounds are more effective under alkaline conditions, it is now clear that this is not generally true, and that for some strains of bacteria a reverse relationship obtains. Explanations of the observed differences are now being sought.

(vi) *Mould Growth Studies.*—A detailed study has been commenced of the water relations of a mould which has been isolated in these laboratories from spoiled food, and which is unusually well adapted to growth under dry conditions. The organism is able to grow in media when the activity of the water is between 0.65 and 0.95 approximately, no growth occurring in the usual moist media in which the activity of the water is usually around 0.99.

5. *Meat Investigations (Brisbane).*—(i) *General.*—The continued difficulty of securing highly-trained scientific workers is a severe handicap to the operations of the Division's laboratory at Cannon Hill. Consideration is now being given to the possibility of securing suitable men from overseas. Recently, the addition of an engineer-physicist to the Cannon Hill staff enabled at attack to be made on a good deal of maintenance work on plant, equipment, and other problems which have been held in abeyance for some time.

The appointment by the Division of Animal Health and Production of a special officer to investigate beef cattle production in Australia, principally in Queensland, directing attention particularly to specifying, by measurement and analysis, the standard trade grades of carcasses, and associating them with factors such as age and environment, has resulted in arrangements being made between the two Divisions concerned for the officer doing this work to make his Brisbane headquarters at the Cannon Hill laboratory. Its location on the property of the Queensland Meat Industry Board will facilitate the carrying out of certain aspects of the work attempting to establish correlations between the animal on the hoof—both as to its physical conformation and as depending upon such factors as age, nutritional history, and environment—and the beef derived from it.

Consultation work continues to make a considerable demand on the available resources of the laboratory. Assistance has been given to those associated with many phases of food preservation and transport, in some cases necessitating laboratory investigation, plant survey, and the specification or design of suitable equipment.

Following negotiations to secure additional laboratory space, the Queensland Meat Industry Board agreed to place at the disposal of the Council a further 6,500 square feet of floor space adjacent to that which the Council now occupies. Since that time, a further optional site on the property of the Queensland Meat Industry Board has been suggested. If the latter site is adopted, a new building could provide more modern and much better facilities than could be had by extending from the present laboratory.

(ii) *Plant and Equipment.*—Work on the tenderization of meat has made necessary the setting up of much special equipment, some of which had to be specially fabricated. Included in this was the installation of lamps emitting ultra-violet radiation, chiefly in the neighbourhood of 2537 A.U. Considerable work on design, adjustment, and calibration of instruments and equipment has been carried out for other Council for Scientific and Industrial Research laboratories.

(iii) *Maturation or Tenderizing of Beef.*—During the strike in the Queensland meat industry last year, beef of improved eating quality was supplied to the public in the Greater-Brisbane area. The meat trade believed that a good deal of the improvement was due to the tenderizing of the beef, brought about by the omission of chilling immediately post-slaughter. While experimental work indicated definite improvement in tenderness following post-slaughter holding of beef at temperatures of approximately 72° F. for 24 hours, as compared with the usual industrial chilling practice, microbial counts on the beef were so high as to make such a method, under existing conditions of slaughter-floor hygiene, totally impracticable for operations in the Greater-Brisbane area during the summer months. It was obvious that any tenderizing brought about by this means would make the control of microbial proliferation essential to a degree which is quite impossible at the present time.

Work was continued on the influence of ultra-violet radiation in retarding microbial proliferation, the work being carried out in two rooms enabling the beef to be held under identically similar physical conditions of temperature, relative humidity, air circulaton, and time. The left quarters were stored in one room where they were subject to ultra-violet radiation, the right quarters being identically disposed in a duplicate room without radiation. Microbial counts indicated a definite retardation of microbial proliferation in the room where ultra-violet radiation was employed, the retardation being, generally, almost as much in the case of areas which received no direct radiation as those which did. The differential results in retardation of microbial proliferation which one should have expected in respect of distances of surfaces sampled from the light sources, and the angle of incidence of the radiation were not consistent if ultra-violet light had been entirely and directly responsible. This finding, coupled with the fact that the areas which had no direct radiation showed definite retardation of proliferation, suggests that a good part of the effect may be only indirectly due to ultra-violet radiation.

In connexion with the retardation of proliferation on areas so disposed that they received no direct radiation, it is impossible to say, at present, how much of this, if any, is due to the reflection of the ultra-violet from the walls of the room, since no measurements of reflection from these surfaces, at 2,537 A.U., have so far been made. The question as to how much of the effect, if any, is due to ozone produced by the ultra-violet radiation is being thoroughly investigated.

(iv) *Investigations on Ozone.*—In connexion with several phases of the work of the Division, the estimation of ozone is important. Studies suspended at the outbreak of war are again being actively carried on. Considerable work was done on sampling procedures and the estimation of very low concentrations of ozone. It has included a study of the increase in sensitivity of the potassium iodide method, as a function of pH. A number of points have been studied where, in both sampling and analytical techniques, quite erroneous estimations might result.

Further work has included tests for the detection of oxides of nitrogen and hydrogen peroxide in the air from the ozonizer. Methods for eliminating the oxides of nitrogen have also been studied; they involve control at the point of production, or, when produced, by absorption. One absorption method, while perfectly satisfactory, also eliminates carbon dioxide. It is doubtful, therefore, whether this method is practicable, at least in one case where the ozonized air is to be used in bactericidal studies, since the elimination of carbon dioxide might be definitely open to question on the basis of bacterial metabolism requiring it.

Concentrations of about one part per million of ozone in the atmosphere cannot, at present, be satisfactorily obtained directly from the ozonizer, but work is proceeding to get consistently constant concentrations much lower than this. Such concentrations are at present obtained on the basis of dilution of air containing about 250 to 300 parts per million of ozone. So far, consistency of concentration of ozone in air, using the dilution method, is not entirely satisfactory. Work is proceeding to find way and means of making it so.

(v) *Collagen-Gelatin Studies.*—Further work was done in connexion with the estimation of proline in the hydrolysis products of gelatin, using the ammonium rhodanilate method for its determination. Various workers have given values for the proline content of gelatin much lower than that last reported by Stein and Bergmann, of 17.5 ± 0.5 per cent., the values previously obtained in this laboratory also being lower than this. The Division's latest work, using a modified technique, gave a figure nearly equal to that given by Stein and Bergmann.

(vi) *Insect Damage to Beef Casings by Dermestes vulpinus.*—Rather serious losses in industry caused by the attack on beef casings by the insect *Dermestes vulpinus* was referred to the Division. Previous work here had shown that the insect was particularly susceptible to heat, subjection to temperatures of approximately 60° C. for periods as short as twenty minutes being apparently sufficient to kill it in all stages of its life cycle. Since heat treatment of casings was not desirable, the effects of low temperatures were studied. Temperatures down to approximately — 3° C. were not sufficient to destroy the insect in all stages. Casings

with plentiful insect material were placed in jars and subjected to temperatures of approximately —15° C. Apparently, complete kills of all stages were obtained, certainly in 64 hours, possibly much less. Following this, space-temperature surveys were made, by the use of thermocouples, in standard-packed cases of these beef casings, to determine the rate of temperature reduction when the case was stored in a freezer at —15° C. Based on this investigation, advice was tendered to interested parties in the meat industry.

(vii) *Karl Fischer Reagent.*—For the purpose of its possible employment in certain laboratory procedures, particularly those involving the accurate estimation of very small amounts of moisture, methods employing the Karl Fischer reagent were studied, essential equipment made and set up, the reagent prepared, and experimental work commenced.

(viii) *General Microbiological Work.*—In connexion with the possible early return to export chilled beef, further microbial surveys were made for estimation of the extent to which export-standard slaughter-floor hygiene had declined in its years of disuse during the war.

In connexion with problems of meatworks hygiene and the sterilization of cold-storage rooms, investigations have been started on sterilizing agents and methods for their adequate dispersal and use. Atomizing equipment and special bactericidal and fungicidal solutions necessary for this work have been obtained and are now being subjected to preliminary tests before use in investigational work.

Experimental work was done on methods of sampling meat for counts of microbial populations. The method of Garrard and Lochhead wherein dry sterile filter papers, each 4 sq. cm. in area, were pressed on to meat surfaces for 20 seconds, was compared with that where definite meat samples of 1 sq. cm. each were taken with a cork borer. Present indications are that there is no satisfactory proportional correspondence between counts made by the two methods, those obtained by the filter-paper method, as a percentage of those obtained by the cork-borer method, ranging from 8 to 78 per cent. It is quite probable that further work would result in decreasing this spread in proportion, but probably not to a degree sufficiently satisfactory for our work.

6. *Preservation of Fish by Refrigeration.*—Work on the refrigeration of fish which was suspended during the war has been resumed in some degree and the problem of the development of ammonia in shark flesh has been investigated. Samples of shark flesh collected at a fishing port in South Australia have been subjected to various periods of exposure at different temperatures prior to freezing, and the production of ammonia has been determined before, during, and after freezing and thawing; at the same time the growth of micro-organisms which may be responsible for the breakdown of urea and development of ammonia has been followed. Similar measurements are being made on shark flesh which has been cured and smoked after varying periods in the frozen state.

7. *Fresh Fruit and Vegetable Storage Investigations (with New South Wales Department of Agriculture).*—(i) *General.*—The staff of the Fruit and Vegetable Storage Section has been increased during the year by the appointment of a storage officer who will take charge of applied problems, and by the appointment of a plant physiologist who will work on problems of plant tissue physiology. A new storage officer has been appointed to the New South Wales Department of Agriculture and is stationed permanently at the Food Preservation laboratory.

(ii) *Plant Physiology and Biochemistry.*—Investigations on the organization of the plant cell and its relation to cell stability and on the respiration of the cell, with particular reference to organic acid metabolism, have been continued. Some of this work has been carried out in collaboration with plant physiologists in the Universities of Melbourne and Sydney. Experiments on the quantitative relation between the stimulated respiration due to inorganic salts and the amounts of those salts accumulated by the tissue, have given results suitable for publication. It has been shown that the number of molecules of salt entering the cell under optimum conditions is approximately equivalent to the number of electrons eliminated in the stimulated respiration.

Preliminary experiments on the tissue of ripening peaches showed that the rate of respiration decreases rapidly after the tissue is cut from the fruit. This was shown to be associated with the decreasing number of functional cells. Simultaneously the effects of solutions of various osmotic pressures were examined. It was demonstrated that the increasing tendency for cells to break down in water as ripening proceeds is partly an osmotic phenomenon, associated with an initial rapid absorption of water.

Work on apple tissue has been continued. An experiment was designed to determine the relation of cell size, cell number, respiration of the whole fruit, respiration of the cut tissue, suction pressure of the tissue, and total and protein nitrogen to the size of fruit. For this purpose apples with a wide range of sizes were obtained from one tree and examined as soon as possible after picking. This extensive experiment is the beginning of an attempt by a team of physiologists to determine how differences in fruit size, so frequently related to differences in storage behaviour, are correlated with the physiological properties of the tissue. A technique for the sampling and measurement of mean cell size in a fruit has been developed.

The survey of the organic acid constituents of apples in cool storage has been continued. The fruit has now been in store for more than a year and samples are still being removed regularly. In addition to the organic acid fractions, sugar and nitrogen fractions are being analysed and will also be related to respiration.

Work on the physiology of cold injury begun with preliminary experiments on the respiration of orange rind in the Warburg apparatus.

Some time has been spent in examining the possibility of using a radio-frequency technique for determination of electrical conductivity changes in alkali solutions used to absorb the carbon dioxide produced by respiring fruit. This technique appears to have considerable advantages over those at present in use, particularly as it would be faster to operate.

(iii) *Fresh Fruit Storage.*—(*a*) *Skin coatings for apples.*—The results of common storage and cool storage experiments completed in 1945, have been incorporated in a detailed report. The experiment, commenced in 1946, designed to compare the effects on storage of the physiological conditions within the fruit (particularly with regard to internal atmosphere) brought about by skin coating, with the effects brought about by gas storage, was completed. The results of this experiment are being related to the earlier work on skin coating and are to be prepared for publication.

(*b*) *Orchard variability in relation to storage.*—Variability in storage behaviour of apples within trees, between trees, and between orchards in the Orange district is being investigated. The statistical problems raised by this type of experiment have been discussed with several workers interested in the field. The relation of keeping quality in respect of certain disorders, to fruit size and crop size is being observed. This work will follow somewhat similar lines to that carried out by Carne and Martin in Tasmania, since it is generally agreed that more data of this type should be collected for varieties and districts, additional to those used in

the Tasmanian work. Fruit put into cool store in 1946 was examined in November and December, and the new season's fruit was put into store in March and April, 1947. These experiments will probably extend over a period of some years.

(*c*) *Maturity and ripening of papaws.*—In response to a request from growers in northern New South Wales, some investigations of conditions most satisfactory for ripening have been started.

(*d*) *Ripening of Bosc pears.*—Experiments on the ripening of Bosc pears have been continued, with the object of comparing normal and late picked (hormone-sprayed) fruits.

(iv) *Transport.*—In collaboration with the State Departments of Agriculture, officers of the Division have organized a survey of the interstate movement and condition of vegetables. From this survey of a field in which little information had previously been collected, it will be possible to define what problems require immediate investigation and what further information should be collected. Experiments on the transport of beans from the north coast of New South Wales to Sydney have been organized. Frequent large losses in commercial consignments (mostly due to sweating) indicate the necessity for improved methods of handling.

(v) *Dried Fruit Storage.*—Storage experiments with dried apricots, peaches, and pears, started in 1945, are still in progress. These experiments have been directed to studying the effects of storage temperature, initial sulphur dioxide content, and moisture content on the storage life. These experiments are now nearing completion.

8. *Canning and Fruit Products Investigations.*—(i) *Vegetable Canning.*—Field work similar to that carried out during previous years on the optimum maturity at picking of sweet corn grown at Windsor was continued and a considerable amount of additional information was obtained. The relationship between refractive index and moisture has been set out in graphical form for the three seasons during which the work has been carried out; some evidence of a seasonal variation in the relationship is indicated. The information concerning the selection of corn at optimum maturity was applied by the cannery with the result that a significant improvement in quality of the canned product was obtained. Six varieties of sweet corn seed from the United States of America and from local sources were grown and then canned as whole grain and cream-style packs. The need for growing selected varieties of this crop in isolation was made clear from the work.

Canning maturity studies have been made on peas grown at Cowra and Bathurst and good correlations obtained between alcohol-insoluble solids and tenderometer and succulometer readings. Examinations of the canned product are being carried out, and the results will shortly be available for publication. A canning trial to test the effect of the Blair Alkalizing process on the retention of the green colour in canned peas indicated a definite improvement over unheated controls canned at the same time. A slight superiority in colour was still apparent after approximately twelve months incubation at 37° C.

Carrots grown at Hawkesbury Agricultural College are being harvested at weekly intervals and the relationship between maturity and canning quality tested.

Nine varieties of tomatoes grown at Hawkesbury Agricultural College and seventeen at the Experimental Farm, Bathurst, have been canned at Homebush; in addition seven varieties were canned at Leeton Cannery. Severe culling was necessary with the Hawkesbury fruit owing to virus wilt infection, and with the Leeton fruit owing to adverse weather at harvest time.

Two varieties of beetroot were grown at Hawkesbury Agricultural College and canned in different size grades at weekly intervals. Crimson Globe was inferior in colour and flavour to the other variety, Detroit Dark Red. For the latter variety the most economical harvesting age was 68 to 75 days, at which a reasonable total yield and the maximum yield of the best grade (1 to 2 inches) were obtained. Size grading was found to bear a much closer relationship with quality as judged organoleptically than chemical analyses including measurements of total solids, alcohol-insoluble solids, total sugar, reducing sugar and pH. None of these determinations showed promise as an index of maturity.

Three varieties of dwarf green beans (Asgrow Stringless Greenpod, Burpee Stringless Greenpod, and Giant Stringless Greenpod), one butter bean (Kidney Wax), and one pole bean (Blue Lake) were grown at Hawkesbury Agricultural College. Three different size grades from each variety, selected visually, were canned to represent different maturities. No reliable chemical indices of maturity were indicated from measurements of total solids, alcohol-insoluble solids, total and reducing sugars, and pH. A slight but definite improvement in retention of green colour was noted in canned green beans previously subjected to the Blair Alkalizing process, but the darkening of the liquor in the alkali-treated samples was unattractive and offset to some extent the beneficial effect on the beans.

Cauliflower and broccoli are being canned at different maturities as judged by the openness of the flower head. The problem of discoloration in canned cauliflower is being studied and methods aimed at overcoming this defect are being tried. Various procedures for blanching of cauliflower prior to canning are also being investigated.

(ii) *Fruit Canning.*—The fruit programme for 1946-47 was carried out almost entirely in the Murrumbidgee Irrigation Area with the help and co-operation of the Leeton Co-operative Cannery and the New South Wales Department of Agriculture.

The programme included the canning of some 22 varieties of clingstone peaches. These peaches mature at different periods, and the object of the trials is to determine whether there is a suitable variety maturing before or after the standard varieties so that the peach-canning season may be spread over a longer period. Preliminary examinations suggest that four or five of the varieties possess possibilities in this direction. The freestone canning was continued with a reduced number of varieties some of which were canned at Leeton while the majority were packed at Homebush. These products have yet to be examined.

Apricots have also been canned, several different maturities being packed in syrups of varying concentration to determine the optimal sugar concentration for each maturity. Comparisons between packs made of tree-ripened and storage-ripened fruit indicated a definite flavour superiority with the former.

Canned pears were prepared in which varying additions of tin salts, ascorbic acid, and sulphur dioxide were made to the lacquered cans to assess their respective roles in controlling discolouration during storage. Several precanning treatments to control browning of peeled pears were also compared. The treatments comprised holding, in dilute brine, 0.001 per cent. ascorbic acid, and 0.05 per cent. sulphur dioxide. A series of pears packed in syrups containing different amounts of citric acid showed that the addition of acid to the product is desirable, but the optimal concentration may vary between 0.5 and 1.0 per cent., depending upon individual preference.

Encouraging results were obtained with four varieties of rock melon submitted by the New South Wales Department of Agriculture. The melons were canned in diced form in an acidified syrup and also with the addition of passionfruit pulp; both packs were attractive in appearance and flavour.

(iii) *Fruit Juices.*—The work for the greater part of the year was concerned with investigations on the bitter principles in Navel and Valencia orange peel and juice, with a view to eliminating the objectionable bitterness which develops in orange juice within 24 hours of processing. Fundamental work on the nature of the bitter principle was considered necessary in order to fix definitely the mechanism by which bitterness develops and to provide, if practicable, chemical means of control. By means of extraction of the peel in a soxhlet apparatus with benzene, followed by evaporation and recrystallization from alcohol, a product was obtained which yielded bitter aqueous solution at dilution of less than 1 p.p.m. The alcoholic mother liquor also contained an intensely bitter substance yet to be isolated. To obtain large amounts of bitter principle a large-scale soxhlet apparatus was constructed, operating on the usual intermittent siphoning overflow. Using the method of extraction outlined, two apparently identical bitter products have been obtained from both Navel and Valencia peels. For accurate melting point determination, an electrically heated copper block, the temperature of which can be raised slowly or rapidly by means of a rheostat, was constructed, and the operation of melting observed through a microscope.

To obtain a workable yield of bitter principle from canned orange juice involving extraction of twenty litres of liquid, a large-scale liquid-extractor of a continuous nature was constructed which was capable of extracting this volume in seven days. The product isolated from the juices has been shown to be identical with the product from the peels. Measurements to determine accurately the solubility of the bitter principle in water have not been successful, but it appears to be of the order of 0.001 per cent. at 100° C. Chemical work on orange peel has confirmed observations previously made which showed that bitterness in juice from Valencia oranges is related to the use of fungicidal copper sprays on the growing fruit for control of black spot.

(iv) *Can Lacquers.*—Several lacquers were tested for their resistance to preservatized cordials. Two commercial vinyl-type lacquers were found to be satisfactory. Four lacquers were tested against canned sausages but only one was found to give a satisfactory performance. The four sausage lacquers were also tested against processed cheese, and it was found that two were sufficiently resistant to the product to be considered satisfactory. Two lacquers for citrus products were also tested and found to give satisfactory performances.

(v) *Miscellaneous.*—A comparison of extraction methods for passionfruit pulp demonstrated that removal of the pulp by hand was superior to reaming with the usual burr-type reamer, in that settling of the seeds due to removal of their gelatinous covering was eliminated. The reamed pulp also developed a reddish colour differing from the normal fruit colour observed in the pulp removed by hand.

Small samples of locally grown youngberries and boysenberries were supplied by the New South Wales Department of Agriculture and attractive fountain syrups and cordials were prepared from the fruit. A particularly fine flavoured attractive table jelly was also produced from the boysenberries.

Preliminary investigation was begun to observe the effect of calcium chloride in improving the texture of canned apple products. A definite improvement was noted with the use of 1.3 per cent. calcium chloride soak with Granny Smith apple slices, but further work is planned with other varieties more liable to breakdown during cooking.

9. *Dehydrated Foods.*—(i) *Vegetable Dehydration.*—The investigation mentioned in last year's report on the suitability for dehydration of a range of onion varieties has been continued for a third season to determine whether differences between varieties are consistent. Material from some of the seed lines used in the last two seasons was grown at Canberra, and at Griffith. Descriptions and chemical work were done on the fresh onions and examination of the dehydrated products is still in progress. In addition to this material, fourteen strains of Australian Brown, two of Brown Globe, and one of Odourless were received from the Victorian Department of Agriculture. Descriptions and chemical work were done on fresh and dehydrated material.

Last year's work on the dehydration of green peas has been extended. Four varieties were received from Canberra and nine from Griffith. Chemical work and descriptions were done on fresh and dehydrated material. Some varietal differences were noted but the effect of maturity seemed more critical than that of variety. A sample of vined peas from a grower at Richmond was processed, but results were unsatisfactory owing to the poor quality of the raw material. Information was obtained on the uptake by peas of sulphur dioxide from sulphite solutions and on the effect of different drying conditions on the final moisture content of the product. Arrangements for the supply of peas for work in the current season have been made with a grower at Picton, but no samples have yet reached picking maturity. It is proposed to study especially maturity effects during the coming harvest.

Eight varieties of sweet potato grown in Queensland were processed. Yellow varieties gave fairly satisfactory products, but discolouration was severe with white varieties.

Just before the period covered by this report 84 samples of potatoes were received from the Tasmanian Department of Agriculture and were processed during July, 1946. They included 36 varieties, 8 being grown on two soil types and five on three soil types. During the current season some samples of two varieties grown in different districts of New South Wales have been processed.

The factorial storage experiments described in last year's report have been continued. Some material has yet to be removed from storage but the bulk of the examination has been completed and the results tabulated. The data comprise numerical scores for the appearance of the dry material and for the colour of the cooked reconstituted vegetables; they include also the scores allotted for flavour and texture in the tasting tests; ascorbic acid and carotene contents, where the dehydrated vegetable before storage has significant amounts of these constituents; and, for the nitrogen packs, the carbon dioxide and oxygen contents of the atmosphere in the can. All removals after six, nine, and twelve months and some after eighteen months in storage have now been made. A considerable mass of data is available for statistical analysis and it is hoped that this will shortly be begun in conjunction with the Section of Mathematical Statistics, which also co-operated in the design of the experiments.

(ii) *Fruit Dehydration.*—Investigations on the dehydration of apricots, freestone peaches, clingstone peaches, and pears have been continued on lines generally similar to those of last season. With apricots from the Murrumbidgee Irrigation Area, sun-drying was compared with dehydration and sulphuring by fumes of burning sulphur with dipping in a solution

of potassium metabisulphite. The effect of variations in wet and dry bulb temperatures during drying was also studied.

Freestone peach varieties used were Blackburn Elberta and J. H. Hale grown at Bathurst. Maturity was the main factor studied, but with J. H. Hale attention was also given to the use of steam and lye peeling. Clingstone peach varieties used were Golden Queen and Pullar grown at Leeton. Maturity was again the main factor studied. The effect of dipping in acidified sodium sulphite or potassium metabisulphite solution was compared with sulphuring by fumes of burning sulphur, and sliced fruit were compared with halves. Fruit was also dried after different periods of sulphuring.

Work on tray coatings to prevent or lessen sticking of the dried pieces to the trays was continued, using both fresh fruit and reconstituted dehydrated fruit. This work is of particular interest because the sticking of peach slices to untreated trays is severe enough to make their commercial processing impracticable, in spite of the great reduction in drying time compared with half fruits. Castor wax emulsions with 5, 10, and 15 per cent. solids have all given considerable improvement over untreated controls, but the effect was most lasting with trays treated with the emulsion containing 15 per cent. solids. These experiments are being continued.

In the first quarter of the year dehydration experiments were carried out with Josephine, Packham's Triumph, and Winter Cole pears which had been cool-stored at Batlow. It was found that by using certain simple precautions a very satisfactory product could be obtained. The varieties being used this season are Packham's Triumph from Bathurst and Winter Cole from Batlow. Studies of brine peeling are now in progress and sulphite dips and different ways of subdividing the fruit for drying are also being investigated.

(iii) *Meat Dehydration.*—During the year the laboratory at Auburn was brought into operation for investigations on meat dehydration. All the equipment has been installed except a meat extract concentrator which is still being built. The first investigations were concerned largely with exploring the range of conditions which could be used and with training the tasting panel. They also established the favorable effect on the tenderness of cooked dried meat of holding the meat at 34° F. for a period before processing. A statistically controlled experiment, based on the preliminary results and including four cooking treatments, two sizes of mince, two drying schedules, and two grades of carcass has been carried out and the results are now being written up. A study has been begun on the changes in flavour and tenderness of the dried product brought about by progressively increased times of precooking under various conditions.

(iv) *Egg Dehydration.*—Work was continued on the absorption of carbon dioxide by egg powder, especially as affected by the moisture content of the powder and the time of preliminary evacuation before treatment with carbon dioxide. The results of this work are now being written up.

(v) *Fresh Potato Investigations.*—The investigation of the changes in the ascorbic acid and dry matter content of growing potato tubers was continued. Samples were taken at frequent intervals from a plot at Windsor until it was ruined by heavy rain about four weeks before the tubers were due to mature. Two plots at Canberra were sampled throughout the growing period. These trials have yielded valuable data on the distribution of ascorbic acid and dry matter in the tuber as well as on their rates of production.

During the period under review an interstate variety trial was carried out in co-operation with the Departments of Agriculture of New South Wales, Victoria, South Australia, and Tasmania. Plots were located at Guyra and Llangothlin in New South Wales, Ballarat, Geelong, Kinglake, and Kooweerup in Victoria, Mount Gambier and Woodside in South Australia, and Sheffield in Tasmania, where plantings on two soil types were included. Results of chemical and culinary tests and of descriptions of tuber characteristics have been tabulated as the work progressed. Meteorological data for the stations nearest the plots have also been tabulated.

With the assistance of district officers of the New South Wales Department of Agriculture, arrangements were made with three growers in each of seven of the main potato districts of the State (Crookwell, Batlow, Orange, Maitland, Guyra, Ebor and Dorrigo) to grow two varieties of potato, all using the same seed. Examination of the material from this farm trial has been largely completed. Records of yields, tuber characteristics, results of tasting tests, determinations of ascorbic acid and solids content, and meteorological data for the localities concerned have been tabulated.

Samples grown by the Division of Plant Industry at Canberra in continuation of the variety trials carried out in previous seasons have been examined on the same lines as for the interstate and farm trials.

Work is being continued on methods for assessing the cooking quality of potatoes, with particular reference to texture.

10. *Publications.*—In addition to the food Preservation Quarterly, Vol. 6, 1946, and Vol. 7, No. 1, the following papers were published during the year:—

The ascorbic acid and carotene content of some Australian fruits and vegetables; compiled from data obtained in the laboratories of Commonwealth Food Control and the Council for Scientific and Industrial Research. *J. Coun. Sci. Ind. Res.* (Aust.) 20:1-8 (1947).

Huelin, F. E., and Stephens, I. M. (1946).—Catalytic oxidation of ascorbic acid. *Nature* 158: 703.

——(1947).—The influence of ferrous iron in the determination of ascorbic acid. *Aust. J. Exp. Biol.* 25: 17-23.

Huelin, F. E., and Tindale, G. B. (1947).—The gas storage of Victorian apples. *J. Dept. Agric. Vict.* 45: 74-80.

X. FISHERIES INVESTIGATIONS.

1. *Introduction.*—Further progress has been made in the development of the Division's post-war research schedule. All sections of the freshwater estuarine, and inshore programme were extended, extra staff, equipment and external co-operation being secured for the purpose. While the central laboratory is situated at Cronulla, New South Wales, branch stations have previously been established in other States. In Tasmania, improved laboratory facilities are now being made available in Hobart in a building purchased by the Council. In Victoria, laboratory facilities are being made available in Melbourne by the State Department of Fisheries and Game, to replace the accommodation hitherto provided by the Melbourne University, Department of Zoology, and now required for other purposes. In Western Australia, laboratory accommodation was obtained in Perth during the year in place of that which has been provided since 1943 by the State Fisheries Department, which in addition made available much clerical and other assistance. The Division's chemical work has been, and will for the time

being continue to be, carried out at the Institute of Agriculture, University of Western Australia. The generous provision of facilities by these various agencies has assisted in the rapid development of various research projects, many of them in a collaborative capacity. Recently, at the invitation of the Queensland Fisheries Department, a co-operative arrangement was entered into whereby the State will provide living, laboratory, and boat facilities at Dunwich, where the Division will carry out a programme of marine biological research.

With regard to deep-sea investigations, particularly in connexion with pelagic fish occurrences, it was not found possible to resume operations with the M. V. *Warreen* until January, 1947, owing to delays in refitting. The vessel is now engaged in surveys of the marine resources of Western and South Australian waters, having, prior to the Japanese war, completed a general survey of the south-eastern region. In the latter, the Division's policy is now to engage in mass-catching fishery trials on a commercial scale. A fair range of nets is now on hand, a good knowledge of the seasonal and regional runs of pelagic fish has been accumulated over several years of survey, and selected fishermen with suitable craft are working in co-operation with the Division. It is pleasing to record that catches on a commercial scale were made both with the mackerel and purse-seine net and the lampara net, and it is anticipated that progress in the development of the pelagic fishery will now be more rapid. The good trial catches made have attracted considerable attention from commercial interests, which by their co-operation are making it feasible to conduct more intensive trials.

During the year the fish-canning industry has been extended, particularly in Tasmania, and the general adoption of the principle that adequate cold storage provision is essential in order to maintain steady supplies of fish has led to much more continuous production. The agar industry established to supply a war-time need has survived into the post-war period, and has continued to increase, being now of a value at least equivalent to that of the oyster industry. However, in the shark-oil industry, which also developed rapidly in war-time to supply vitamin A requirements, signs were noted that, in some localities at least, attention will have to be given to the adoption of suitable conservation measures.

It is hoped during the coming year to extend the Division's exploratory and survey work to tropical waters. Difficulties arose in connexion with the refitting of the ketch *Taipan*, and steps are being taken to replace it by a vessel which is more generally suitable.

2. *Developmental Work, South-east Australia.*—(i) *Horse-mackerel, Bonito, etc.*—The purse-seine fishing work upon the horse-mackerel, which has been going on for several years in Tasmanian waters, was brought to a promising stage in the autumn of 1947. The Division's recently imported net was made available to a leading New South Wales fisherman, Mr. W. Warn, to test out in Tasmania from his new vessel the 61-ft. *Eden Star*. This vessel soon made two catches of 16 tons each, within the one week—a performance definitely on a commercial level, and far superior to anything achieved in any of the previous pelagic fishing work in Australia. No further catches were made, but it seems clear that this was chiefly due to the net being still a little too short to encircle the more active shoals which prevail towards the end of the season; this disability should be overcome in future. It can at any rate be said that the prospects for the emergence of a Tasmanian mackerel fishery are now fairly bright.

For some few weeks prior to engaging in these Tasmanian trials, the same team of men attempted to use the same equipment, and other similar nets, which were mostly made available by the Division, in the southern waters of New South Wales. During the summer and early autumn, various pelagic fish, including horse-mackerel, true mackerel, bonito, and striped tuna appeared to be quite abundant in this area, but considerable difficulties were encountered with unsuitable weather, inadequate depth of water, wildness of the shoals, &c. The only catch made was one of two tons of bonito taken with a fishing-net in Twofold Bay, but even this was notable as being the first catch of any tuna species taken by surface net in Australia. It was always expected that these difficulties would prove greater in New South Wales than in Tasmania, but nevertheless it is possible that, with the experience and encouragement of the Tasmanian work, useful results may be obtained in time.

(ii) *Pilchards, Sprats, etc.*—Some survey work and fishing trials, utilizing a ring-net made up from materials supplied by the Division, were carried out in respect of pilchards in New South Wales waters during the spring, by private fishermen. However, the fish were not abundant on the whole and most of the shoals sighted were very wild, as a result of which only small catches were made. Some preliminary work was done in respect of drift-netting for pilchards in Western Australia, the experiments indicating that the method has some promise.

A lampara net was made available to another private operator in Tasmania to use upon sprats. The catches were no larger than before but were made more frequently and with many fewer men. These results are regarded as satisfactory by those concerned, who propose to conduct sprat fishing as a part-time operation in conjunction with other work. Using one of the Division's lampara nets, the crew of the *Eden Star* effected a catch of 5 tons of pilchards and sandy sprats off Eden early in June, 1947. This is the largest catch so far made with this net in Australian waters.

(iii) *Demersal Fishing in Tasmania.*—The Division has published a report on the Danish-seining trials by the M. V. *Liawenee* in southern Tasmanian waters over two and a half years. The evidence shows that tiger flathead is practically the only important species available, and that there may be periods of relative abundance or scarcity of this fish continuing for at least two or three years. The final appraisal of the economic prospects of such a fishery can best be made by the trade itself, from the data supplied in the report. The work represented a co-operative effort with the Tasmanian Department of Agriculture.

(iv) *Pelagic Fish—General.*—A report has been completed which summarizes all the available information obtained from boat surveys on the regional and seasonal distribution, evidence of annual fluctuations, &c. of pilchards, horse-mackerel, salmon, sprats, and other non-scombroid pelagic species of south-eastern Australia. The past work with different pelagic fishing techniques has also been reviewed, and tentative suggestions have been made as to the lines along which success is most likely to be attained in future.

The research vessel *Warreen*, since January, has done reconnaissance work between Fremantle and Port Adelaide, including the Great Australian Bight. The primary objective was to survey the occurrence of pelagic fish species, the fish being sampled by trolling gear and by lampara and drift nets. The only considerable catches of tuna were made in the South Australian section of the cruise. Pilchard occurrences were general, and barracouta, an unexploited species in Western Australia, were somewhat abundant east of Esperance in May.

3. *Biological Investigations.*—(i) *Pilchards.*—It has now been demonstrated that there are three major groups of these fish in Australian waters, namely: (*a*) an eastern group, in New South Wales and southern

Queensland, which spawns and is most abundant at the surface in winter; (*b*) a southern group, in Victoria, South Australia, and (less plentifully) in Tasmania, which spawns and is most abundant at the surface in the summer and early autumn; and (*c*) a western group, in Western Australia below the Tropic of Capricorn, which spawns and is most conspicuous in the winter.

Of these three, the study of the eastern group is virtually complete, that of the southern group well advanced, and that of the western group beginning. The eastern group has been shown by vertebral counts to be itself a series of virtually independent populations disposed in different belts of latitude along the coast, there being at least three of these and possibly more. In this respect, and also as regards their rate of growth and general life-history, these eastern pilchards more closely resemble the related populations of south-west Europe than they do those of north-west Europe, Japan, or California. Since the pilchard is in such a widespread and variable form in Australia, the finished studies should assist in the task of the general appraisal of the Australian environment and the recognition of different geographical sections thereof.

Observations on annual fluctuations of pilchards on the New South Wales south coast and in Port Phillip Bay have been continued, since this will be the main point on which research can assist any fishery that may arise for this species.

(ii) *Anchovies.*—The general life-history studies are approaching completion. There was a very great occurrence of these fish in Port Phillip during the winter of 1946, which served to draw the attention of fish-paste processors to the importance of utilizing this resource. The Division was successful in helping some of them to obtain supplies by organizing contacts with local fishermen who were seeking outlets for the catch. Evidence is accumulating to show that fluctuations in the supply in Port Phillip Bay refer not so much to actual abundance, but to availability in the shallow waters where the fishermen can catch them. In an attempt to learn more about this and other problems connected with the Bay fisheries, the Division is now collaborating with the Victorian Fisheries Department in a plankton-hydrology programme, with the Department's new boat.

(iii) *Whitebait (of Tasmania).*—The catch of this species for 1946 was a record—about 750,000 lb. This fishery is now one of considerable importance to the local canning industry; the Division is maintaining a constant watch on catch in order to detect any tendency to overfishing of the resource. However, there are yet no clear signs that this is taking place, in spite of the fact that the fish only spawns once and is fished heavily at that time—a practice that has been going on for several years. Apparently the stock produces spawn in excess of what is required to maintain a constant level of recruitment, which is what most investigators have always believed was true of fish generally, although it has been very difficult to obtain clear evidence on the point. However, there can be no doubt that depletion will become evident at some stage if the fishery becomes further intensified.

(iv) *Barracouta.*—It is proposed to conduct research upon this species on a much larger scale than in the past, in view of the fact that this species is now the most important single item in the Australian catch, and, further, because it is probably the only important species already being utilized and seeming to have considerable possibilities for still greater exploitation. (There are of course considerable possibilities of exploiting hitherto neglected species of pelagic fish.) In response to the wartime and post-war demand for more fish, the barracouta catch rose from about 4,500,000 lb. in 1941-42 to about 14,500,000 lb. in 1945-46, whereas most of the other major elements in the catch rose very little, and some have even declined in output, over the same period. Moreover, virtually all this barracouta production came from Victoria and Tasmania only, whereas it is now known that the species is also plentiful throughout South Australian waters and along the southern coast of Western Australia, though virtually unfished over most of this great area. The barracouta is a good, cheap, easily caught, and plentiful species, and could occupy the same relative position in our fisheries economy as does the herring in that of northern Europe. A good deal of economic research has already been carried out upon the subject in the Division, but the life-history and movements of the species are still very little understood. Collaboration in these studies with fisheries investigators in South Africa and New Zealand would be desirable, since the distribution of the barracouta is circumpolar in the southern hemisphere.

(v) *School Shark (Notogaleus rhinophanes).*—This is the most important shark used in Australia for the production of liver oil, having a high vitamin A content. Concern having been expressed by the fishermen with regard to maintenance of supplies, the Division has undertaken a general biological study of the species. Since the investigation was commenced in May, 1946, a preliminary survey has been made of the main shark fishing ports of Victoria, Tasmania, and South Australia. The amount of work at sea has been curtailed considerably because of the bad weather experienced in Bass Strait. However, data on the food, type of fishing grounds, and breeding habits have been collected, and a report on the biology of the school shark is being prepared. There is considerable diversity of opinion among the fishermen themselves about the source of the stock of fish and their migratory habits.

In order to obtain accurate data on the migrations and growth rates, a tagging programme, using the Petersen type tag on the dorsal fin, was commenced in March, 1947, at Portarlington (Victoria), when 618 young school sharks varying in size from 14 to 34 inches were tagged and released. The majority of the tagged sharks represented the second year age-group, with length measurements averaging 24-26 inches. All were caught on handlines by fishermen assisting the officers of the Division with this programme. To date 26 tagged sharks, representing a 4 per cent. return, have been caught at widely scattered places in Port Phillip Bay. Four were released again after the number of the tag and length measurements had been taken.

It is now hoped to enlarge the scope of this programme by tagging at several widely separated localities in Victorian and Tasmanian waters.

The livers of two Tasmanian dogfishes, *Flakeus megalops* and *Squalus fernandinus,* were submitted for determination of the vitamin A content of their oil. Although the male *Flakeus* livers contained a relatively high potency vitamin A oil (12,000-18,000 I.U. per g.) that from females was very low (1,600 I.U. per g.) which was also the case for both male and female liver oils of *Squalus fernandinus* (1,600-3,200 I. U. per g.). With such low potency values, these small livers would not justify the labour in obtaining the quantity required for commercial production. However, there is a possibility that these dogfishes at present unused might be considered as a basis for fish-meal with fairly high vitamin A content.

(vi) *Trawl Fish.*—(*a*) *Flathead.*—During the summer, the developing egg was obtained by artificial fertilization and from tow-nettings. It may be distinguished only with difficulty from the eggs of several other species spawning over the same season. Throughout the year, sampling at the Sydney Fish Markets and the steam trawler wharves was continued for length,

weight, gonad condition, and season of spawning in the different localities, otoliths for age-determination, and raciation measurements. This work brought in a large supply of otoliths for the calendar year 1946, which has now been worked up on a method adapted from Hodgson's (1939) method of sampling herring shoals, showing that 0.15 per cent. of the year's catch by numbers (0.05 per cent. by weight) were spawned in about January 1945, 3.88 (1.86) per cent. in 1944, 29.47 (20.34) per cent. in 1943, 45.95 (43.42) per cent. in 1942, 16.38 (24.35) per cent. in 1941, 3.45 (7.34) per cent. in 1940, 0.63 (1.78) per cent. in 1939, 0.08 (0.84) per cent. in 1938, and 0.01 (0.30) per cent. in 1937. Therefore, 88 per cent. of the weight of flathead taken was derived from only three year groups, and half of this was from one year group only. It is believed that 1946 was an unusual year (see below) but it seems certain that the fishery is dependent in this fashion on a very few year groups, so that if one year group "fails" the effect should be felt quite noticeably two or three years later.

It is expected that the age-analysis of the commercial catch will be continued as a routine from now on; such work most quickly and surely shows up changes in the stock of fish caused by heavier or lighter fishing, or by natural fluctuations.

The trawl fish statistics from 1942 onwards have been worked up. The catch in 1939 was normal; as a result of the call-up of vessels, it fell in 1940 to nearly half, in 1941 to less than a third; from then till the end of 1944 there was but one steam trawler and (later) a few seine net boats working, taking about one-tenth of the normal catch. The fishery was therefore rested for four or five years, after which time the numbers of seine net boats rose rapidly to a peak of about 70–80 (actually working in any one month) in the summer of 1946-1947, and nine steam trawlers (as compared with twelve to fifteen before the war) working in 1947. One trawler is to-day equivalent to six and a half seine net boats in actual catch, so there was a minimum total effort of about 135 seine netter units during last season as compared with about 100–105 units before the war.

It has been abundantly demonstrated in Europe that where an overfished area is rested the catch per effort increases. The converse is presumably true: that if a fishery is rested and when fishing is resumed the catch per effort does not rise, then that fishery was not heavily overfished—assuming that a severe natural fluctuation does not mask the recovery. It appears that in the New South Wales trawl fishery there has been only a slight increase in catch per effort since 1942, suggesting that the fishery before the war was not being heavily overfished. The actual figures for average monthly catch show that the abundance of flathead has in the post-war period fallen alarmingly, whereas the catch of other fish (not flathead) has remained constant. It has been possible to show from length-frequency data for 1941, 1945, and 1946 that there has almost certainly been a "failure" of the flathead year-group spawned in the summer of 1943-1944. Presumably, next year should show a recovery of the flathead catch. Meanwhile, the demersal fleet is concentrating on morwong to make up its catches.

(*b*) *Other trawl fish.*—A biological study of the morwong has begun. It is hoped gradually to embrace the other species of trawl fish into the general programme.

(vii) *Australian Salmon.*—From investigations made to date, the nature and state of the fishery in the different States has now been fairly well documented, the south-east corner of Australia and latterly, south-west Australia, being the important areas. During the last decade the collection of salmon statistics has been improved in most States, but there is probably room for further improvement particularly as to the catch per unit of effort. In any case these figures should be closely watched and cross-checked in Western Australia, Victoria, and New South Wales.

There would appear to be discrete eastern and western stocks of salmon, but so far no morphometrical differences (other than growth) have been distinguished; this work has yet to be finalized. There is surprisingly little exact record of the season of spawning in the different localities, nor is there an adequate estimate of the size and age at first spawning. Nothing is known of the eggs and larvae in this country, or of the locale of spawning (save from hearsay). Two tagging programmes (1939 and 1942) were carried through in south-eastern Australia; the results were sufficiently satisfactory to justify a much fuller programme using the same tagging technique. Returns were 6.4 and 3.2 per cent. of releases, fish being recovered up to 200 days after release and 150 miles from the place of release; the 1942 experiment revealed a most marked and definite migratory movement. A large collection of otoliths was examined, but discarded in favour of the scales for age-determination. In general, it can be said that this is a fishery which is probably not yet being worked to capacity either in the west or the east.

In Western Australia, the salmon processing industry has been intensified during the year, and a biological programme has been conducted at the main catching centre of the fishery, near Hopetoun. Several surveys have been made, in the course of which tagging has revealed that shoals remain on the beach for about a fortnight or so before being replaced by other shoals. There are interesting differences in the behaviour of these shoals as compared with those in the eastern States, and thus far there has been no evidence that the salmon avoid an area where intensive netting has been carried on. On an aerial survey in August the location of all beach shoals eastward to Cape Arid was plotted.

(viii) *Black Bream.*—Biological investigations on this important estuarine fish were continued during the year.

(*a*) *Taxonomy.*—A report dealing with the taxonomy of Australian breams has been completed for publication; it incorporates results of examination of breams fom localities representing the entire coastline of Australia. Six species are observed to occur in Australia, five being referred to the genus *Acanthopagrus* Peters and one to *Austrosparus* Smith. These names replace the prior incorrect use of *Sparus* Linne and *Chrysophrys* Quoy and Gaimard for the Australian species. Bream formerly identified with *australis* Günther are shown to constitute a complex to two species; *australis* (yellow-fin bream) occurs only on the east coast as far south as the New South Wales-Victorian border, and is replaced on the south and west coasts of the continent by a species new to science (southern bream). The species *berda* and *palmaris*, together with *latus* (a new record to Australian seas), occur throughout the tropical regions only. *Acanthopagrus berda*, *A. latus*, and *Austrosparus sarba* (tarwhine) extend throughout the Indo-Pacific region to Africa and Japan, but the yellow-fin bream and southern bream, the main commercial species of Australia, are strictly endemic.

The geographical distributions of the five Australian species of *Acanthopagrus* conform closely with the recognized marine faunal zones. All six species have been illustrated and re-described from Australian material, and a complete revision has been carried out in generic limits, nomenclature, synonymy, and distribution.

(*b*) *Tagging.*—The black bream tagging programme has been extended considerably during the past year, covering principally the summer season in northern New South Wales and southern Queensland. Previously, 1,415 fish had been tagged during winter months. The total has now been brought to 2,841. The percentage of return tags has been small, being 0.7, representing a total of eighteen tags, of which eleven have been returned from Tuggerah Lakes, two from Wallis Lake, and one each from Lake Macquarie, Richmond River, Tweed River, Noosa River, and Frazer Island. In all cases the fish had not moved from the estuary in which they were tagged, and only one was taken on an ocean beach adjoining the entrance of the estuary. So far this evidence suggests that the species does not effect a seasonal coastal migration as does the mullet, but only leaves the estuary temporarily under conditions of freshets and for spawning.

Periods between release and recapture varied from four to 305 days and a few fish had shown slight increase in growth. There is some evidence that tags affect the welfare of the fish generally and that many are rubbed off. The bream recovered from the Richmond River appeared to have spawned during the period between release and recapture.

(*c*) *General.*—Market measurements and other data covering the general biology of the species have been accumulated over the period as a routine procedure.

(ix) *Mullet (Mugil dobula).—Western Australia.*—Analysis of the accumulated data on the Western Australian stocks of the sea mullet has been completed, and further work is being carried on to round off the study. A similar examination of the yellow-eye mullet has been commenced. An intensified tagging programme has, with occasional interruptions, been under way since November, 1946. Besides sea mullet and yellow-eye mullet, several hundred fish of other estuarine species have been tagged during the operations. Twenty-one tagged sea mullet and eight yellow-eye mullet have been returned, all except one from the river system in which tagging occurred. The exception, a yellow-eye mullet, travelled a minimum of 25 miles from Wonnerup esturay to Bunbury Breakwater. The period between release and recapture of these fish varied between 24 hours and seven months.

The mullet conservation scheme initiated by the State Fisheries Department in March, 1942, on the recommendation of the Division was abandoned by the State Government on 15th September, 1946. No proof was obtained that the scheme played a significant part in affecting the total population of mullet in the three western estuaries.

(x) *Southern Bluefin Tuna.—(a) Western Australia.*—The *Warreen* during its cruises from January to May was able to take only the young fish (2–15 lb.) in Western Australian waters. Larger fish occur, and the area around King George's Sound is the only locality in Australia where the great spawning adults weighing several hundreds of pounds are regularly observed. The migrations and seasonal distribution of this species in Western Australia are not yet understood; the future cruises of the *Warreen* are expected to throw light on the subject.

(*b*) *South Australia.*—Restricted data were available for the 1946-1947 season from private anglers. However, the *Warreen's* trolling results in April and May indicated a large aggregation of bluefin in the southern portion of Spencer Gulf and Western Kangaroo Island. These fish were of the IV-year and older age classes. The largest fish taken by *Warreen* weighed 78 lb., but a 97-lb. tuna was taken by private anglers.

(*c*) *Eastern Australia.*—Good catches of the IV-year group (averaging 23 lb. fish) were made at the beginning of the season. No evidence was forthcoming, however, that the younger year classes, viz., III-year class, 15-17 lb., and II-year class, 5-6 lb., were at any time plentiful. In general the best reports of tuna occurrences came from the southern portion of New South Wales.

(xi) *Shellfish Investigations.*—(*a*) *Scallops.*—Shortly after the start of the present scallop season a memorandum was sent from the Division to the Tasmanian Secretary for Agriculture expressing grave concern for the future of the D'Entrecasteaux Channel scallop fishery. It was pointed out that the number of boats working in 1946 was more than double that in 1942, and that although the catch for 1946 was a record, the catch per unit effort had not recovered with the removal of war restrictions and, in fact, was less than half of that of the pre-war period. It was also pointed out that most of the smaller beds in the Channel were quite worked out, and that the great bulk of the catch in 1946 came from one bed; reports this year are that this process is continuing, and that virtually all boats are now working the one bed. The European scallop beds have proved to be as vulnerable to overfishing as natural oyster beds, and it appears that good fishing may be had right up to the time of extinction of a bed because of the necessity in these Lamellibranchs of a dense population to achieve efficient spat fertilization. An inspection of the sea-floor was made at three different places in the Channel by means of diving operations.

Good returns were had from the 1946 tagging programme, and revealed certain faults in the technique used that year. In 1947 a different type of tag was used, over 4,000 scallops were tagged, and considerable efforts were made to obtain an efficient and even scattering throughout the beds covered. In the new method the tag is wired to the shell instead of being affixed by a heated wax. The method is quicker, requires fewer personnel, and the shellfish is out of water for a shorter period. Apparently the mature scallop does not move far in the natural state and so a random "sowing" must be made if tag returns are to show the catch percentage of the stock. Tags are now being returned from this year's work, and also some from 1946.

A new system of scallopers' returns was arranged with the State Fisheries Department for this year, designed to indicate the intensity of fishing by beds. The Division's field officers are also making a weekly count of the boats on each bed. The scallops are being sampled weekly for length, weight, and gonad maturity. Hydrological and planktological sampling was maintained throughout the year, and the drift bottle returns are coming in satisfactorily.

Wire tags were used on some scallops that were placed in a wire cage and sunk on a scallop bed. By regular examination it is hoped to obtain precise data on the rate of growth of the shellfish.

The results of the previous two years' field collections have been worked up and have proved not very helpful. The scallop apparently grows very slowly in its later life and consequently distinctive modes are absent from the length-frequency polygons. It was also impossible to obtain consistency in the statistically significant differences of length/width and length/shell-weight ratios within quite restricted areas and within year groups within an area.

(*b*) *Oysters.*—Spat fall observations in Port Hacking have been completed, and the results are being analysed. Testing of materials in the attempt to discover a cultch-collecting material as an alternative to the dwindling supply of black mangrove sticks has continued. The fibro-cement slats which caught in the 1945-1946 season have retained their catch, and good growth has been exhibited. Tarred batons nailed into frameworks and set out in nests of a dozen frames

have caught well. Excellent catches have been obtained on untreated sticks of the white cypress pine (*Callitris glauca*). Tarred cypress pine sticks gave almost as good a catch. Sticks treated with creosote, however, proved to be repellent to the oyster larvae.

The white cypress pine sticks fulfill the three requirements of (*a*) being in plentiful supply, (*b*) being reasonably low in cost, (*c*) being of a length suitable for handling. Deterioration has been very slight. The New South Wales Forestry Commission has co-operated by supplying the sticks and in applying mechanical tests for deterioration. In view of their good catch, the cypress pine sticks will be transferred to the growing lease to test their ability to retain the oysters for the required three-year period.

Attention has been given to the choice of areas in Western Australia and Tasmania suitable for the introduction of the Japanese oyster (*O. gigas*). There is no oyster industry in these States, and quite possibly an introduced species might succeed and form the basis of a canning industry as has happened on the west North American coast.

It is considered that the rock oyster occurring in the Abrolhos Islands, Western Australia, is suitable for commercial exploitation, and advice is to be given to the Abrolhos Islands Board of Control on suitable methods of cultivation.

Further observations on winter mortality were made during the winter of 1946 in New South Wales. Analysis of results to date indicates that: (*a*) mortality decreases upstream; (*b*) mortality reaches its maximum at approximately the same time each year (the middle two weeks in September in George's River); (*c*) degree of crowding of oysters is not significant; (*d*) significant mortality occurs in transported oysters only if they are brought into the area just before the winter season; (*e*) the mid-inter-tidal level (approximately the adopted growing level) is at about the centre of the killing zone; (*f*) microscopic examination and bacterial identification reveal no pathogenic organisms; and (*g*) exposure of healthy oysters to possible infection from "sick" oysters does not bring an incidence of the disease. These biological conclusions are apparently capable of being interpreted along with those derived from hydrological studies (see later). It would appear that the best method for avoidance of the disease would be for the oysterman to remove his trays in winter from the danger zone to a higher zone. Mid-July is recommended as a suitable time for this relaying of oysters from the point of view of securing maximum growth rate while avoiding mortality.

(xii) *Marine Crayfish.*—(*a*) *Panulirus longipes, P. ornatus, P. versicolor, P. pencillatus.*—Further surveys in Western Australia show that *P. longipes* extends to North-West Cape about 250 miles north of Carnarvon as an onshore species. The three other species, the so-called "Coral" crayfishes or "North-West" crayfish of Western Australia, also occur along North-West Cape Peninsula.

During nine months of the past year juvenile crayfish of a total length range of from 2 to 3 inches were taken at Sandy Cape, north of Jurien Bay, and in seaweed areas at the northern end of the western reef of the southern group of the Abrolhos. Crayfish of this size have been found to moult every four to six weeks, with a length increment of from 20 to 25 per cent., at least up to a total length of 4 to 5 inches. While the presence of these small crayfish may be due to an abnormal retardation of growth in some specimens, it is perhaps more likely that it is due to the lodging of puerilla at these places over an extended period.

Spawning periods are known to occur over a range of about six months when the whole area of distribution of the species is considered, while surface drift conditions along the coast are such as to make it possible for larvae to enter one area from a number of very widely spaced points. Such a condition would be of importance in the maintenance of the fishery.

An extensive marking programme designed, among other things, to give information on growth rates, population movements, and population density, has been commenced in the Abrolhos. Approximately 7,000 crayfish were marked up till June. In addition a test, which has been in operation since March, has been designed to sample the population present and the recruitment to a limited area throughout the season. Two crayfish marked in the southern group were recovered at the Wallabi Group, 30 miles northward.

Tissue-darkening effects were apparent in the cannery pack. Experiments showed that a good white pack could be obtained by using a short cooking period (10–15 minutes) and adding hydrated aluminium chloride at the rate of four in 1,000,000 parts to the brining water. The cannery is now operating this technique satisfactorily.

Phyllosoma in early stages were obtained in tow nettings at the Abrolhos up to the middle of April, but none after that time. A bulletin "Marine crayfishes (spiny lobsters), family Palinuridae, of Western Australia" has been prepared, embodying the results of investigations up to date.

As before, a large amount of the work done during the year was carried out with assistance of volunteer labour from fishermen and others. Work on littoral ecology has continued, and an Honours student of the University of Western Australia is studying the zonation of the fauna and flora of a section of reefs in the Cottesloe area.

In a charter flight over the Abrolhos in exceptionally clear conditions, shelf edge sites for marking experiments were selected. Areas of live coral hitherto unfished were mapped, and a submarine bank lying about 14 miles westward of the Easter Group and about 7 miles long was found. These areas have since been successfully exploited by fishermen. Local flights have been made with private pilots and underwater reefs have been located. These areas have now been entered by local crayfishermen.

With the assistance of Messrs. J. Baseden and R. Page of the fishing boat *Maori Lass* a wire pot has been devised, based on the New South Wales type but spot welded and with a detachable bottom. In a test of 280 hauls the wire pots took 1,688 crayfish, whilst the batten pots in general use took 765. During a gale lasting 6 days none of 33 wire pots, set in exposed situations, were lost. The loss of cane and batten pots set by fishermen in less exposed situations was general and of the order of 2 to 3 per 30 pots.

Tests were made of sisal pot ropes, using wattle and red bark tans, and copper naphthenate and creosote (proportion 4 to 1), in their resistance to sliming and underwater rotting. The tests are continuing, but the results to date (on a purely utilitarian basis) show a working life of three months for the copper creosote treated ropes as against two months for the tanned ropes in the southern group of the Abrolhos.

(*b*) *Jasus lalandii.*—In conjunction with Professor V. V. Hickman, University of Tasmania, it is proposed to undertake a study of the life history of the Tasmanian crayfish, *Jasus lalandii*. A locality has been selected where larval stages have been obtained by tow netting, and it is proposed to continue the investigation at this locality during the coming season.

(xiii) *Penaeid Prawns.*—A programme of investigation on the life history of the commercial penaeid prawn (king prawns, school prawns, and greasy back prawns) has been undertaken in collaboration with the Department of Zoology, Sydney University, during vacations. The main aim is the assessment of size

distribution in relation to habitat, hydrological conditions, and seasonal migrations, with a view to improving the commercial catch. Preliminary work carried out principally concerned the development of suitable techniques and methods of research. A small otter trawl net was designed and built for purposes of field sampling, independently of commercial catches. Initial sampling was from market consignments, and some field work was carried out in the Manning River, Port Stephens, and Tuggerah Lakes estuary systems.

(xiv) *Muttonbird Investigations.*—(*a*) *Mortality census in eastern Australia.*—This survey has been carried out for a number of years at Bate Bay, Cronulla, and in 1946 it was extended by observations made at beaches at Narooma, Newcastle, and Southern Queensland. In all years since 1942 there has been a relatively low mortality. In 1946 all the recording stations reported similarly. Previous correlations with pelagic fish occurrences have suggested that low mortality years coincide with years of good abundance of pelagic fish, and high mortality (such as occurred in 1941 and 1942) with a scarcity of pelagic fish, in particular southern bluefin tuna.

(*b*) *Study of the commercial muttonbird industry in Tasmania.*—At the request of the Tasmanian Government, a survey was made of the biological aspects of the muttonbird industry at the Furneaux Group, north-eastern Tasmania, in March, 1947. The investigation, which included the banding of about 700 young muttonbirds, was made to ascertain the relative degree of escapement of the young from the commercial operations and to determine the effect of the intermittent grazing on the bird islands.

(xv) *Plankton Investigations.*—A limited number of hydrographical and plankton stations is being worked by the M.V. *Warreen* during her fishing surveys.

(*a*) During the year a paper was prepared and is in press, on the volumes of the net plankton taken by the B.A.N.Z.A.R.E. in the Australian Antarctic Quadrant.

(*b*) The publication of further work on *Euphausia superba* in the Discovery Reports necessitated the rechecking of the larval series of Australian Euphausiids. The report on this group is being modified accordingly.

(*c*) A section on the behaviour of fish shoals in South Australia in relation to feeding habits was written as a contribution to a Divisional paper on fish shoals.

(*d*) A systematic sorting into families and genera of the collections of *fish eggs and larvae* obtained by M.V. *Warreen* during the years 1938-1942 is being carried out, and special attention is being paid at the present stage to representatives of the orders Iniomi, Isospondyli, Anacanthini, Pterosomata, and families Monocanthinidae, Triglidae, and Carangidae, which represent the greater percentage of the larval forms present in these collections. Collections made beyond the 100-fathom line consist principally of larval Isospondylid and Iniomid fishes, many of which in their adult phases have not yet been recorded from Australian waters. Plankton collections made close inshore contain larval stages principally of Gobiidae and percoid-like species. Those made in the vicinity of the Capricorn Group of the Great Barrier Reef System contain a large number of larval Labrid fishes. Larval flatfishes, gurnards, and myctophids (lantern fishes) are the commonest components of the collections generally.

Current collections of plankton made in east coast estuaries at various stations of the New South Wales coast have been sorted for fish eggs and larvae. Further attention has been given to the characterization of eggs and larvae occurring in the estauries of the east coast, and some time has been devoted to the preparation of a second report for publication on the post-larvae of Australian fishes. This deals with the families Atherinidae, Mugilidae, and Pseudomugilidae, the representatives of which all appear to be estuarine spawners.

(xvi) *Hydrological Investigations.*—(*a*) *Oceanic investigations.*—(i) *South-east Australian sector.*—From the data that have been collected about onshore hydrological conditions in this sector, it is now possible to derive the seasonal cycle of changes at various localities therein. The seasonal cycle of changes at the extreme sampling localities within this sector, i.e. Port Stephens (New South Wales) and Maria Island (Tasmania), displays similar trends in respect of physical and chemical conditions. The temperature and density cycles have maximum and minimum values at similar times of the year. The nutrient cycles are also very similar, with maximum values during the spring quarter and minimum to zero values throughout the remainder of the year. These cycles reveal the essential homogeneity of the onshore waters of this sector and demonstrate the lack of any cold water intrusion into the east Tasmanian area during the period of observation. The findings are of considerable importance in relation to fish and other fauna appearances in the area.

(2) *South-west Australian sector.*—During the period 1944-46 a considerable number of hydrological sampling stations have been worked in the onshore region of this sector. The resulting data suggest that these onshore waters are isolated from the oceanic waters in some areas, to such an extent that the physico-chemical properties of the onshore waters are practically identical with those of the adjoining estuarial waters. This isolation has a marked effect on chemical nutrients. For example in the Geraldton area during the summer months, it has been found that there occurs almost complete exhaustion of the chemical nutrients of the onshore waters from the shore to the Abrolhos Islands. This exhaustion persists because of the lack of mixing between these onshore waters and the nutrient-rich deeper waters lying offshore.

(3) *Mean sea level studies.*—The mean sea level data from Port Hacking over the period 1942-46 have now been prepared for publication. Although there is a multiple interaction between wind, ocean currents, and mean sea level, it has not been possible to isolate these components on a quantitative basis. There is some evidence to suggest that mean sea level varies some three to four months in advance of the oceanographical conditions, and efforts are being made to put this on a quantitative basis for use in prediction studies.

(*b*) *Estuarine investigations.*—(1) *South-east Australian sector.*—A considerable bulk of information on both the hydrology and the nutrient chemistry of the bottom deposits has now been obtained from the principal estuarine systems of this sector and is being summarized and plotted. The zonation and nutrient features of these estuarine systems have now been established and can be used in the comparative evaluation of other Australian estuarine systems. The analysis of the bottom deposits has been undertaken in view of their probable role in the nutrient requirements of benthic estuarine organisms. The data so far obtained suggest that the fattening of the rock oyster is governed by the phosphorus content of these bottom deposits. This theory has been experimentally tested at the Division's lease at Shell Point, where oysters grown over a phosphate-enriched mud flat appear to have conditioned better than comparable stocks on the same flat. As an index of biological activity in these bottom deposits, the C/N ratio has been found most

reliable, and a comparative study of the variation of this ratio in the estuarine systems so far investigated is now being made.

(2) *South-west Australian sector.*—A comparative study of the principal estuarine systems in this area has been made from the data collected during 1944-46. It has been found that these estuarine systems differ from those in the South-east Australian sector in the following respects:—(i) They are freshwater-dominated. This appears to be an effect of the concentration of the rainfall in the late winter and early spring months. Because of their relatively small size and shallowness, the huge volume of water discharged into them during the rainfall period practically eliminates all marine waters from them. As a consequence of the weakly developed tidal penetration of marine elements into these estuarine systems, these fresh-water conditions persist in some cases even during the summer period of negligible rainfall. (ii) The nutrient level of the waters in these estuarine systems during the winter months is comparatively high as a consequence of a higher phosphate run-off. These nutrients do not persist, however, and for the greater part of the year zero to minimal values are encountered. Moreover, the lack of stability of these systems reduces the possibility of planktonic elements utilizing the nutrients and establishing themselves in them. (iii) The annual scoring of these estuarine systems by flood waters has led to an almost complete elimination of the silt deposits which are a recognized feature of the estuarine systems of the South-east Australian sector. Such silt as is found is fairly rich in nutrients but does not provide a sufficiently stable substrate for the development of bacterial and micro-planktonic populations therein. This lack of microbiological activity is reflected in a low C/N ratio.

(*c*) *Oyster hydrology.*—(i) *Mud flat enrichment experiment.*—During the past year continuous sampling of the mud from a phosphate-enriched plot and adjoining non-treated plots, at surface and sub-surface levels, has been carried out at Shell Point, George's River. The results of this sampling are subject to a big sampling error and have not yet been fully interpreted, but there is evidence of a considerable seasonal change in nutrient condition of the mud on these tidal flats. Although insufficient biological measurements of the oysters grown over the enriched and untreated plots are available for comparison, there is plenty of indirect evidence to suggest that the growth rate of the former is considerably faster than that of oysters grown on non-treated portions of the tidal flat. It is proposed, therefore, to repeat this experiment on a commercial scale during the forthcoming growing season at a number of localities in George's River.

(2) *Spatting tank.*—The heating elements for installation in the spatting tank at Shell Point have now been tested and found satisfactory. With their installation the effect of temperature upon gonad maturation and spawning will be studied at Shell Point during the forthcoming year.

(3) *Winter mortality studies.*—The data concerning mud flat and water temperature at Shell Point during the 1946 winter mortality season have now been examined. From the results it has been possible to deduce the existence of a cold wave front in advance of the main body of water over the tide flat. The temperature of this cold wave front is often as much as 5°–7° C. lower than the main body of water behind it. It is felt that under certain circumstances this cold wave front could be lethal to oysters. To obtain more information about its spatial distribution over the mud flat and its persistence on the ebb tidal phase, another six thermometer elements and a continuous recording thermograph have been installed at further points along the observation jetty. It is probable that the poor nutrient condition of the majority of oysters at the time winter mortality is prevalent contributes to the destructivenes of this disease, and an endeavour is being made during the winter of 1947 to test the effect of added mud nutrients on the oysters' resistance to the disease.

(xvii) *Seaweed Investigations.*—(*a*) *Taxonomic studies.*—During the year taxonomic studies have continued on the Australian algae. This work is an essential foundation for any development of industry involving Australian seaweeds. During these studies certain species new to Australia have been found, while the known range of other species has been considerably extended. The results are being reported in a series of papers.

The systematic study of the main Australian agar-producing genus, *Gracilaria*, was completed some time ago, and attention is now being directed particularly toward the *Pterocladia-Gelidium* complex. This complex of species is used extensively overseas for agar production. Already the known range has been extended, and the ecological conditions controlling reproduction have been determined, for one of Australia's more prevalent species of this complex. At least one species of the complex has been found for the first time in Australia, while it is likely that others will appear as the study proceeds. Many identifications have been made of specimens submitted and overseas exchanges of named herbarium material have been made in a number of instances.

(*b*) *Seaweed surveys.*—Recently, the chief agar-manufacturing firm has stated that it required some 800 tons of dry seaweed per annum, and it is proposed to make a survey of Queensland waters in the coming season. The present known beds are estimated to yield a possible 300 to 400 tons in good seasons.

(*c*) *Agar research.*—This work has been temporarily suspended owing to inability to collect the seaweeds required. Preliminary tests on the production of agar from blended weeds along the lines of the Japanese agar industry were not successful, but only small quantities of the seaweeds were available and these were of poor quality.

(xviii) *Bacteriological Investigations.*—(*a*) *Spoilage and marine bacteria.*—Statistical studies of the reactions of isolated pure cultures of bacteria showed that there was little promise of a statistical classification. Further studies on the variation of determinative characters of individual cultures is in progress.

(*b*) *Bacteria attached to submerged slides.*—A method has been devised of growing and isolating in pure culture some of the bacteria present on fouling plates during the early stages of fouling. The suggestion of Zobell that bacterial films are necessary to subsequent fouling by barnacles, mussels, Bryozoa, etc. is being studied. The identity of fouling bacteria can only be determined with accuracy when some finality is reached concerning the studies discussed in (*a*) above.

(xix) *Fouling.*—Fouling research has continued, studies being made on weekly, fortnightly, and monthly growths on exposed plates at Botany Bay and Port Hacking, and on monthly plates at Eden, Ulladulla, and Sydney Harbour. These tests are quantitative and qualitative, and show some very interesting possibilities. This is the first time that continuous studies of the early stages of fouling have been made. One interesting point is a new record for Australia of one of the Bryozoa which is a very common fouling organism in Moreton Bay, Sydney Harbour, and Port Hacking. Cultures *in vitro* of some common fouling organisms are being made with a view to reproducing, under controlled laboratory conditions, combinations of fouling organisms found to occur naturally.

(xx) *Fisheries Technology in Japan.*—An officer was appointed as a member of the Australian Scientific Mission to Japan. He was attached to the Natural Resources Section of General Head-quarters, S.C.A.P., and prepared reports on the seaweed, fish reduction, and fish liver oil industries of Japan, as well as making inquiries into the status of fisheries research there. He brought back a quantity of scientific literature which is now in the Divisional Library and furnished reports on specific matters which lay within his scope. He has prepared an illustrated report on his inquiries which covers fish canning, oyster culture, and other matters as well as on the subjects for which S.C.A.P. reports were prepared. This report is now being published by the Secondary Industries Division of the Department of Post-war Reconstruction. His conclusion was that the Japanese had little that is new in fisheries technology which could be applied under Australian conditions, the most interesting developments being in the edible seaweed industries and in the use of whale livers for vitamin products.

(xxi) *Aerial Observations of Pelagic Fish.*—During the years 1946-47, there were three series of aerial observations of pelagic or surface-swimming fish:—

(*a*) *1st July to 16th August,* 1946.—The flights during this period (except for those during the return to Melbourne from Western Australia via the coast) were carried out wholly in Western Australia and were a continuation of those begun at Melbourne on 28th March, 1946, which, up to the end of June, 1946, had covered portion of the waters of Victoria, Tasmania, South Australia, and Western Australia.

The organization of the flights and the effectiveness of the observations in the July-August period in Western Australia were impaired by the extraordinary boisterous wet weather which prevailed over practically the whole of the period, especially in the southern half of the State where the survey was mainly centred. An added difficulty was met in respect to the non-availability of aircraft for the work during portion of the time.

The chief object of the survey was to make contact, if possible, with the vast body of pelagic fish, the main portion of which was first observed from the air in the western portion of the Great Australian Bight on 20th May, 1945. Only one opportunity presented itself for an inspection of this area and even then for only portion of it. This was during a moderately calm period which occurred for only a few hours on 30th June when a position (approximately Lat. 33° 03′ S; Long. 124° 08′ E.) about 40 miles northwards of Israelite Bay was reached. The aircraft was then forced to return to base in order to effect a landing before sunset. Despite the rather poor conditions for pelagic fish which prevailed, quite a large body of pilchards was observed—between 800 and 1,000 shoals. Other visits were paid to this area later, but on no occasion were the conditions found to be suitable. It should be understood that no direct means of obtaining first-hand information as to the prevailing weather conditions in the Great Australian Bight was available to the aerial observer at his base at Esperance.

The Australian gannet, which breeds in Victoria and Tasmania, is usually an important indicator of the presence of certain kinds of pelagic fish such as pilchards and mackerel. The aerial surveys have now established that these birds migrate each year to South and Western Australia in numbers which constitute a considerable portion of the total population. These birds were again found in these areas and as far north as Shark Bay. During the return flights to Melbourne about the middle of August, gannets were noticeably scarce in Western Australia and relatively few were seen in South Australia. It is significant that the birds were observed to be nesting on Lawrence Rock gannetry near Portland, Victoria, on the last day of the survey, 16th August.

The flights on the south coast of Western Australia disclosed larger bodies of salmon than have been seen hitherto from the air in that State. A series of observations at three different periods showed that the fish appeared to be migrating westwards from the south-eastern portion of the State. Such observations could not possibly be made (certainly not under existing conditions) from shore or from a boat in this area. The discovery of a shoal of salmon travelling westwards at a point near Pt. Culver in the far east of the southern waters of the State may possibly be of high significance to the study of the migrations of this species.

One remarkable feature observed in the Bight during the flight from Esperance to Ceduna on 13th August was a vast aggregation of seaweed on the beach portion of the shore of the Bight from broadly Long. 126° 30′ E. to Long. 128° 35′ E., a distance, allowing for the curvature of the beach, of at least 150 miles. This seaweed, which was probably *Posidonia australis,* was so densely congregated that the water was stained to the point of opacity for about half a mile from shore and at times it was quite discoloured even beyond that distance. It is surmised that this great aggregation was due in part at least to the boisterous weather.

(*b*) *4th April to 22nd April,* 1947.—At the request of an Australian firm interested in manufacturing fishery products, aerial support was given to a test, based on the north-east of Tasmania, for the capture of tuna by various methods; a private plane was chartered for the purpose. It was expected, on past experience, that tuna (especially striped tuna) would be found in appreciable numbers. Eventually, most of the area extending east of Wilson's Promontory to Gabo Island (including the Ninety-Mile Beach of Victoria) thence southwards to Flinders Island, thence down the east and south coasts of Tasmania to South-West Cape, was observed under good conditions. Particular attention was given to north-east Tasmania, since that was where the company's relatively small fishing boat (36 feet long) was based and where it was hoped the fishing tests could be made.

Some tuna, horse-mackerel, and salmon were found but in very small quantities compared with what was to be expected at this period. Muttonbirds (at least in daytime) were extraordinarily scarce in eastern Bass Strait and along the east and south coasts of Tasmania despite the fact that great numbers were nesting on islands in the vicinity. It is significant that these birds were found plentifully in association with the small crustacean (*Nyctiphanes australis*), commonly known as krill or whalefeed, in the area west of Wilson's Promontory. This area is not favoured by the striped tuna despite the fact that krill is one of their favourite foods. Striped tuna appear farther east in Bass Strait and especially east of Flinders Island.

Since they wished to make direct contact with tuna shoals at sea, the company's representatives were advised to proceed to an area east of Flinders Island in which some shoals had been seen from the plane. When the aircraft came up with the boat at the rendezvous after a lapse of nearly 24 hours, it was seen that the boat had just passed through several large shoals of tuna without seeing them. A message was dropped directing the boat to retrace its course and, eventually, the shoals were met. However, it was evident to the aerial observers that the boat party could not see the shoals until they were quite close to them; in fact, as the person in charge of the boat party frankly admitted afterwards, the shoals could not be seen more than about 200 yards away. No more striking illustration could have been afforded of the

ease with which pelagic fish occurrences, especially in the open sea, can, and do, escape detection by observers in boats.

(*c*) *22nd April to 20th May,* 1947.—The flights undertaken during the previous series (4th to 22nd April, 1947) showed tuna to be scarce in north-east Tasmania at a time when on past experience, they might have been expected to be plentiful. It was considered desirable, therefore, to ascertain if this relative scarcity applied to the whole range of their normal distribution in Australia or whether it was only of local significance. Approval was granted for a new series of observations and the aircraft was again chartered for the purpose.

During the period 22nd April to 20th May, a survey was made of the south coast of New South Wales, eastern Bass Strait, and the east and south coasts of Tasmania. This survey was aided by very good weather in its early stages, and a large body of striped tuna, accompanied in parts by Australia salmon and a few bluefin tuna, was discovered within about 12 miles from shore in an area about 70 nautical miles long bounded by Green Cape, New South Wales. (Lat. 37° 15′ S.) to a point about 20 miles west of Cape Everard (Long. 148° 51′ E.). These shoals were observed on three successive days (30th April to 2nd May) under very tranquil conditions, but no perceptible movement of the main body of the fish could be detected. Observations were then abondoned in this area and the aircraft proceeded southwards to Tasmania. Seabirds were comparatively scarce but it was clear that some of the shoals were feeding. Muttonbirds and prions in small numbers were found associated with the tuna in the western portion of the occurrence. Not a single boat was observed in the area of this great occurrence during the flights.

Some very large shoals of dolphins, or "porpoises" as they are more commonly known in Australia, were observed here and elsewhere throughout the whole of the area surveyed; indeed, it was noticeable throughout this survey that porpoises tended to gather in large shoals comprising, broadly 500 to 1,000 individuals. A shoal of 1,000 porpoises is a large one in Australia, notwithstanding accounts which are heard from time to time of shoals comprising "hundreds of thousands" or "millions". Most of these shoals were travelling swiftly and purposefully in various directions as if in search of food.

During the first few days of the survey, observations were also made on the New South Wales coast as far north as Jervis Bay but nothing of note was seen and a search of the whole beach area disclosed only an insignificant amount of Australian salmon.

Subsequent observations in the Tasmanian area, including the Furneaux Group, were generally inpaired by strong winds which set in from the west for the first time for months, according to local reports.

Krill was again observed in the area west of Wilson's Promontory and several observations established its presence in that area from the beginning of the previous survey (4th April) to the termination of the one under review (20th May). A report from the pilot of the chartered plane, who had become acquainted with krill during the surveys, established that this very important fish food was still present in large quantities in the area west of Wilson's Promontory on 31st May.

To what extent, if any, fluctuations in the tuna population of eastern Bass Strait during the late summer and autumn are affected by a possible failure of the great mass of krill (observed over the years on several occasions from the air in western Bass Strait) to "spill over" into the generally warmer waters of eastern Bass Strait is a subject, in the opinion of the aerial observer, worthy of close and early investigation.

Only on one occasion during this present survey did suitable conditions present themselves for aerial observation of the mackerel area in Tasmania. This disclosed that mackerel were still present in large quantities in Tasmanian waters, especially in the Oyster Bay—Marion Bay areas and outside Maria Island. Some lesser occurrences were noted, particularly in the St. Helens and Storm Bay areas.

A vast shoal of Australian salmon 600 yards long and of an average width of 75 yards was found densely congregated on the beach near Harley Point, Cape Barren Island, in the Furneaux Group, on 3rd May. At a moderate estimate the shoal contained 3,000 tons. Apart from this notable occurrence, salmon were not plentifully observed in north-east Tasmania but the observations at sea (as distinct from surveys of beach shallows) were marred on all occasions by unsuitable surface conditions. The presence of a considerable number of Shy Albatrosses in the waters east of Flinders Island towards the end of the survey suggested the presence of fish.

As is usual on aerial surveys, valuable observations were made and photographic records were obtained of coastal features and of such objects as the nesting places and distribution of seabirds, some of which are important indicators of the presence of certain species of fish. During this survey a record was brought back for the first time, during aerial observations, of Shy Albatrosses on the Newstones in the far south-west of Tasmania. Here a colony of these birds comprising several thousands was found.

4. *Publications.*—The following papers were published during the year:—

Blackburn, M., and Fairbridge, W. S. (1947).—Report on the Danish-seining trials by the M.V. *Liawenee,* in southern Tasmanian waters. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 404-13.

Humphrey, G. (1946).—Endogenous respiration in homogenates of oyster muscle. *Aust. J. Exp. Biol.* 24: 261-7.

Kesteven, G. L. (1946).—The theory and methods of fisheries biology. Mimeo. pp. 159.

——(1946).—The coefficient of variation. *Nature* 158: 520-1.

——(1947).—On the ponderal index, or condition factor, as employed in fisheries biology. *Ecology* 28 (1): 78-80.

——(1947).—Population studies in fisheries biology. *Nature* 159: 10-2.

May, V. (1947).—Studies on Australian marine Algae. III. *Proc. Linn. Soc. New South Wales* 71: 273-7.

Serventy, D. L. (1947).—Report on commercial tuna trolling tests in south-east Australia. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 136-50.

Tubb, J. A. (1947).—On the occurrence of *Alepas pacifica* Pilsbry in Tasmania. *Rec. Aust. Mus.* 21: 383-5.

—— (1947).—The Tasmanian scallop (*Pecten medius* Lamarck). 1. First report on tagging experiments. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 202-11.

Wood, E. J. F. (1947).—Agar in Australia. Coun. Sci. Ind. Res. (Aust)., Bull. 203.

—— (1947).—Scientific research in Japan. *Aust. J. Sci.* 9: 144-5.

XI. METROLOGY.

1. *General.*—As a result of the cessation of the war work of the Division, it has been possible to devote more attention to the maintenance of standards and associated research. The Division, however, has been

handicapped by the loss of experienced staff and continued inability to replace this staff. Interference has also been caused by the work on extensions to the laboratory building.

Other Divisions of the Council have continued to take advantage of facilities in the Division for the design of special equipment and also to have precision equipment, such as balances, reconditioned and adjusted.

The Division is represented on many Committees of the Standards Association of Australia and has presented reports for the clarification of various issues. The formation of the National Association of Testing Authorities has required some preliminary work in the preparation of a report to the Advisory Committee.

Formal visits of inspection of the Division have been made by groups from engineering institutions, educational establishments and manufacturers. During the year, 304 certificates, reports and statements of examination were issued.

2. *Measurement of Length and Associated Quantities.*—During the war years it was necessary to base all measurements of length on end standards, with some control by interferometry. It was not possible to make the types of measurements which require to be based on line standards, nor was the control of the longer standards as accurate as is desirable for a Standards Laboratory.

During the latter half of the year, the Chief of the Division visited the Standards Laboratories of the United States of America, Canada, Britain and France, and overseas suppliers of metrological equipment. As a result orders have now been placed for line standards, comparators and associated equipment which will enable the maintenance of all standards of length, and the calibration of surveying tapes, to be carried out in the most accurate manner.

The end standards measured last year at the Bureau of Standards, United States of America, and the laboratories of the National Research Council, Canada, were returned and measured again at this Laboratory. The agreement between all the results of measurement is satisfactory. The end standards have now been sent for further measurement to the National Physical Laboratory.

Further studies in interferometry have been made. Among the results of this work are improvements to the accuracy attainable with the length interferometer, and a new method of calibration of the extensometer comparator.

The divided circle of the 40-in. circular dividing engine has been calibrated. Preliminary work has been started on the producton of accurately divided circular scales.

Government Departments and industrial organizations continue to make frequent use of the Division for calibration of their working standards, for advice relating to precise or difficult measurements and for the undertaking of work beyond their normal facilities. An example of the latter is the measurement of two large electric motors in course or erection. Equipment designed and made by the Division enabled measurement of the 7-ft. diameter rotors and corresponding stators.

For the Commonwealth Surveyor-General, several surveying tapes were calibrated and their coefficients of thermal expansion determined. Further work on the effect of friction in the use of such tapes has been undertaken.

Several measurements of coefficient of expansion have been made including that of an invar standard to be used by the Commonwealth Experimental Building Station, and the determination of the change in shape of a piston corresponding to an increase from room temperature to working temperatures.

The Division has been requested by the Department of the Navy to make the final acceptance tests on certain large gear-hobbing machines about to be erected. Equipment for making these tests has been designed and constructed at the Laboratory.

Continued use is being made of the facilities for the determination of surface finish, for the calibration of extensometers and for other precise measurements.

Progress has been made with other investigations not mentioned above, such as the determination of particle size distribution in fine abrasives, the use of low presure air gauging, and th measurement of thickness of coatings.

3. *Measurement of Mass and Associated Quantities.*—A primary standard kilogram of platinum-iridium was ordered from the Bureau International des Poids et Mesures and is at present on its way to Australia. A reference standard kilogram and a reference standard pound were received on loan from the National Physical Laboratory. The values of the reference and working standards of the Division have been determined on the basis of these two standards.

Three more of the balances ordered in 1940 have been received during the year. One of these is the largest precision equi-arm balance in Australia and will be used *inter alia* for the calibration of large capacity measures up to 10-gallons. Another is a hydrostatic balance of unusual design which will enable the determination of densities of solids and liquids to be made to a very high order of accuracy.

Investigations are continuing into the suitability of various locally produced materials for the construction of standards of mass of high stability. A primary standard pound was verified for the Government of Victoria.

Graduated glassware continues to be received for calibration from Government bodies, industrial laboratories, and manufacturers. On behalf of the New South Wales Milk Board, an investigation was made into certain apparent discrepancies between the weight of milk loaded into railway tank cars at a country depot and the weight received at the city depot. This investigation involved the design and manufacture of a special type of hydrometer for measuring the density of the milk. This hydrometer can be used with equal accuracy in opaque and clear liquids.

4. *Applied Mechanics.*—Examination of Materials Testing Laboratories for equipment, methods and qualifications of staff, is being continued on behalf of the Inspection Services and at the request of industrial organizations. Attention is being given to the improvement of the accuracy of calibration of various types of physical testing machines and to the development of improved and simplified methods of examination.

Instruments of various types have been received for examination, and investigations are proceeding for improvement of the accuracy of their calibration.

Growing demand is being felt from industry for advice and assistance in vibration measurement. An electromagnetic vibration pick-up with certain unusual features has been designed and constructed. Motion between a seismically mounted permanent magnet and coils induces electromotive forces in the coils. The pick-up is connected to a cathode ray oscilloscope which indicates the magnitude and waveform of the vibration being measured. Units of this type have already found considerable use, mainly in the balancing of rotating machinery such as steam turbines. A miniature electromagnetic vibration pick-up is well advanced. This is being developed from the type mentioned above and will have special applications, its weight being less than 4-oz.

XII. ELECTROTECHNOLOGY.

1. *General.*—During the last two years, the efforts of the Division have been concentrated mainly on the establishment of the derived electrical standards and on the facilities for making precise measurements in terms of them. Although there still remains a great deal to be done, it is now possible to undertake electrical measurements of most types to an order of accuracy higher than that normally required by industries and research establishments.

As a result of this progress, it has been possible to give greater attention to research of a more fundamental nature (although some of the work on the establishment of standards may be considered in that category). Research activities are being developed in two main directions, namely the electrical and magnetic properties of materials, and mathematical instruments. In the former of these, work has been confined so far to the properties of dielectrics. A separate section of the Division deals with each of these two studies, but both are very closely associated with the measurement sections.

The applied Electronics Section is still concerned mainly with problems arising within the Division, and this demand will continue for some time to come. However, it has been possible to undertake one major external problem in connexion with aerial surveying.

2. *Direct Current.*—Two new pieces of equipment have been constructed in order to extend the range of D.C. measurements. One of these is a mains-operated stabilized D.C. supply, continuously variable from 100 to 1,600 volts, which obviates the necessity for installing a high-voltage battery. The other, using a Lindemann electrometer, provides for the measurement of resistance up to 10^{17} ohm. This equipment is at present operating in a temporary form, and the final design is in progress. Otherwise, there have been no significant developments, and the Section continues to meet all demands made on it for D.C. measurements.

3. *Alternating Current.*—The completion of the electronic control of the sine wave alternator set—the principal source of supply for A.C. measurements—has been delayed for several months owing to the movement of the Division into new quarters. This work will proceed as soon as the set has been reassembled, and in the meantime it is possible to make only those measurements in which a mains supply is permissible. A very satisfactory mains-operated electronic stabilizer has been developed and is very helpful in this regard, but can only replace the sine-wave set in limited circumstances.

Modifications have been made to the electrostatic voltmeter, of the N.P.L. pattern, to eliminate troubles due to surface potentials and vibration, and to provide stability over a longer period for convenience in operation. An experimental model has been subjected to extensive tests, and a final model is now under construction.

A precise voltage transformer has been designed and constructed in the laboratory to enable the useful measuring range of the electrostatic voltmeter (45 to 110 volts) to be extended down to 0.9 volt.

The electrostatic voltmeter has hitherto proved overseas to be the most suitable instrument for the precise measurement of alternating voltages. It has, however, the disadvantages inherent in a direct-deflection instrument, and efforts have been made in the laboratory to develop a null comparator, using a dynamometer instrument as the indicator. Tests on an experimental equipment indicate a possible accuracy comparable with that of the electrostatic voltmeter, and considerably greater convenience. This work cannot be completed until the controlled sine-wave supply is in full operation.

The equipment for the calibration of current transformers is now being reassembled, in new quarters, in its permanent form. Good progress is being made in the design and construction of equipment for the testing voltage transformers, but it will be some months before this is ready for use.

Apparatus for the direct measurement of high voltage is still in the design stage. The equipment for the measurements of magnetic properties of iron is all ready for assembly in the Laboratory, but space has only recently become available for its installation and testing.

4. *Audio Frequency.*—There has been some delay in setting up the audio frequency measuring equipment in new quarters, owing to shortages of various building materials and fittings. In particular, the establishment of a set of bridges for the maintenance of the standards of capacitance and inductance cannot proceed further until the air-conditioning plant is in operation. However, sufficient equipment has been set up to enable most demands for measurements to be met.

Much of the work at audio and high frequencies is being done in co-operation with the Materials Section, which requires facilities for measuring permittivity and power factor of dielectric materials over a complete range of frequencies up to 10,000 Mc/s., and possibly even higher. Initially, it will be sufficient, in most frequency bands, if measurements can be taken at fixed frequencies arranged approximately in a logarithmic scale (e.g. 100, 300, 1,000, 3,000...Mc/s), and attention is being given at present principally to the completion of facilities for those measurements. A bridge is being developed in the laboratory to cover the range from 10 kc/s. to 10 Mc/s. Overlapping part of this range, a Q-meter is being used in association with a dielectric test set, of N.P.L, pattern, for frequencies above 1 Mc/s.

For measurements of frequency, a temporary standard in the form of a quartz oscillator, with a stability of the order of 1 in 10^6 is in operation, but will be replaced in due course by a set of three quartz oscillators with associated equipment, which are being produced by the British Post Office. When these are installed, a stability of 1 in 10^8 will probably be attained.

Equipment is being developed for the rapid measurement of frequency by comparison with a standard source. This will consist of an electronic counter which determines the number of cycles of the unknown oscillation in a given time interval determined by the standard source. The counter is in satisfactory operation, but the development of a suitable "gate" circuit for timing will be delayed until the standard quartz oscillators have been installed. This work is being done in association with the Mathematical Instruments Section.

5. *Radio Frequency.*—The development of measuring facilities at high frequencies is being carried out jointly with the Division of Radiophysics. The programme of development is being determined partly by the requirements for impedance measurements associated with reseach in dielectrics, but in general, efforts are being directed towards the measurements of (*a*) impedance, (*b*) power and voltage, and (*c*) frequency, throughout the radio-frequency spectrum.

As part of the dielectrics programme, a dielectrometer has been designed, and is now under construction, for permittivity and power factor measurements in the range 100-300 Mc/s. This instrument consists of a co-axial line resonator loaded by a flat sample of the dielectric under test, the dimensions of the sample being the same as those required in the N.P.L. dieelectric test set. The power source is a lighthouse oscillator which can be tuned within the working range by an adjustable cavity.

For the range 1,000-10,000 Mc/s a M.I.T. Co-axial Dielectrometer is on order from the United States of America and should be received shortly. In addition, for frequencies near 3,000 Mc/s, a variable frequency technique based on the M.I.T. stabilized klystron generator may be used as an alternative.

Some attention has been given to the improvement of impedance measurements using a slotted co-axial line, and good results have been achieved within the range 60-220 Mc/s.

Work on the measurement of "live" quantities has been directed along two main lines. For measuring extremely low power, it is necessary to have a standard source of power in the form of a noise generator, either diode or thermal. The diode generator provides a very convenient method of measuring power at ultra-high frequencies, and its errors at those frequencies have been studied both theoretically and by comparison with a thermal generator. It is now possible to use diode generators in the laboratory as standard sources of power at frequencies up to several hundred Mc/s, and it is hoped to extend this range up to 3,000 Mc/s by means of a modified design.

The above methods are applicable to the measurement of power of the order of several hundred micromicrowatts. For power ranging from several microwatts up to 20 or 30 milliwatts, a thermistor bridge technique has been successfully applied.

For the measurement of frequency, selected harmonics from a stable oscillator of comparatively low frequency are compared with the signal under examination. It has been shown possible to use this technique with frequencies as high as 24,000 Mc/s.

6. *Properties of Materials.*—(i) *The Treatment of Glass, Steatite, and other Siliceous Compounds for the Improvement of Electrical Insulation Resistance under Moist Atmospheric Conditions.*—Most of the work in this programme has been devoted to an investigation of the effect of varying carbon-chain length on the insulation resistances, at 98-100 per cent. relative humidity, of glass and steatite samples treated with solutions of alkyltrimethylammonium bromides. With most of the treated glass samples, measurements of the contact angles with water have also been made. Workers in the field of flotation have found that the prolonged exposure of minerals to collector solutions sometimes produces a considerable increase in their contact angles towards water; this also occurs with glass and steatite exposed to solutions of quaternary ammonium salts and is accompanied by an improvement in electrical insulation resistance. With oriented adsorbed alkyltrimethylammonium ions, the area subtended by the alkyl chain is considerably less than that occupied on the surface by the trimethylammonium head-groups. Replacement of the alkyl chain by a sterol skeleton may be expected to give better coverage, and experiments with glass and steatite treated with cholestanyltrimethylammonium bromide showed improved insulation resistances and contact angles. Results obtained in the work to this stage have been correlated and prepared for publication.

Some difficulty was experienced in the treatment of glass and steatite with aqueous solutions of the hydrochlorides of amphipathic amines, but good results were obtained in some cases by adjustment of pH or by prolonged immersion. Experiments with these and with the quaternary ammonium compounds are being extended to the treatment of Pyrex and silica.

The results referred to above were obtained with glass and steatite which had been cleaned with chromic acid before treatment. This step can be eliminated, however, in the treatment with a number of the quaternary ammonium compounds and this gives a more useful method for practical purposes. A further improvement in the direction of practical application has been the treatment of glass and steatite with solutions of long-chain amines and quaternary ammonium compounds in benzene. Of the latter, cetylpyridinium bromide and ceryltrimethylammonium bromide were sufficiently soluble. These materials have also been incorporated in varnishes coated on to glass microscope slides for measurement of electrical insulation resistance.

Measurements have also been made of the electrical insulation resistances and contact angles with water, of glass, steatite, and silica treated with alkylchlorosilanes and with other organosilicon compounds. As an example of a practical laboratory application for the methylchlorosilane treatment, a pH meter in which the valve had been treated gave more consistent results at high relative humidities than before treatment.

Promising results were obtained in experiments on the treatement of a cotton and a woollen textile material with methylsilicon amines for the improvement of water-repellency.

The effective treatment of mica with methylchlorosilanes required the removal of adsorbed ions both before and after treatment. By this means it was possible to improve the insulation resistance of mica exposed to near-saturated conditions by a factor of about one thousand.

Most of the results obtained in tests with organosilicon compounds are being reported elsewhere.

(ii) *Polar Dielectrics.*—A programme has been commenced on the relationship between the molecular structure and dielectric properties of electrical insulating materials. Several previous workers in this field have studied the dielectric effect of introducing small quantities of cetyl palmitate into paraffin wax. Workers overseas have derived an equation relating the carbon-chain length and relaxation time of a polar solute in solid paraffin wax solution, on the assumption that the orientation of a polar molecule in an electric field results from the rotation of the whole molecule, rather than of a small portion adjoining the polar group. It appears likely, however, that two classes of polar substances are possible: (*a*) Compounds in which orientation of the polar group requires rotation of the whole molecule, e.g. ketones. (*b*) Compounds in which orientation of the polar group can occur by rotation about a single bond, e.g., secondary alcohols.

The behaviour of compounds of group (*a*) should be in accordance with the equation referred to above, whereas with those of group (*b*), the relaxation time should be independent of carbon chain-length. The programme in this field will involve the measurement of the dielectric constant and loss angle of solid solutions of a series of ketones and secondary alcohols in several different pure paraffins. As a preliminary step, it will be necessary to determine the effect of the position of the polar group on the dielectric properties of a long-chain polar molecule and for this purpose a series of eicosanols and eicosanones are being prepared in which the alcohol and ketone groups, respectively, are in the 1, 2, 4, 6, 8, and 10 positions. The solvent to be used in these preliminary experiments will be n-dotriacontane, a quantity of which has already been prepared.

The measurement of dielectric properties is to be extended to protein solutions, and preliminary experiments are in progress to determine the most suitable form of apparatus for this work. Probably the most important property of proteins is their ability to adsorb smaller molecules, as for example, in the action of an enzyme on its substrate, or the possible adsorption of amino-acids during the reproduction of genes and viruses. It is hoped that it will prove possible to detect such adsorption by its effect on the relaxation time of the protein as measured by its orientation in an alternating electric field.

7. *Applied Electronics.*—Most of the activities of the Applied Electronics Section have been confined to the development of measuring equipment within the Division, and are described elsewhere.

The section has undertaken the design of a plotting mechanism, asociated with the airborne components of a "Shoran" radar equipment, for use in aerial surveying. This plotter will enable a Shoran-controlled aircraft to follow a series of straight, parallel courses and will provide for automatic operation of a camera at predetermined points, so that complete photographic coverage of an area may be obtained without undue overlapping. In addition, an aided-laying attachment to the Shoran equipment has been developed in order to simplify the accurate following of the Shoran range echoes.

8. *Mathematical Instruments.*—The design of a differential analyser, having approximately twenty integrators, is approaching completion, and most of the components are in hand. The instrument will differ from the conventional type in that electrical interconnexion will be used between the various units. The basic unit consists of an integrator, of the disc, ball and cylinder type, together with variable-ratio gearboxes in the drive to the displacement lead-screw and in the output. The unit will also include the necessary electrical transmitter and motors, which operate on a step-by-step principle. Additional units comprise a number of differentials and general purpose gearboxes, a group of plotting tables, which may be used either as input or output, and a recording unit for displaying results in tabular form.

The use of an electrical system of interconnexion not only reduces the setting-up time for a given equation, but also greatly simplifies the mechanical design since it admits the possibility of a unit type of construction.

It is proposed that the instrument should be used initially in some investigations relating to radio propagation for the Division of Radiophysics, but it is expected that it will become more generally available in a reasonably short time.

Attention is being given to the question of electronic digital computing machines. In the machines already in existence or in the design stage overseas, two alternative principles are used. In one type, the computation is performed in the decimal notation throughout, whilst in the other, a binary system is used. The work of the Division in this field is at present concentrated on an examination of the properties of various types of decimal and binary counter, and on the development of binary-decimal converters. In addition, an attempt is being made to produce a decimal counter enclosed in a single evacuated envelope, in order to avoid the considerable number of valves and other circuit components which are necessary in decimal counters of more conventional types.

9. *Publications.*—Mimeographed reports have been prepared on mains-operated D.C. and A.C. voltage stabilizers, on electrical circuit components, and on the measurement of very low power at ultra-high frequencies. One report has been submitted for publication and a number of others are in final form, ready for submission to appropriate journals.

XIII. PHYSICS.

1. *General.*—The changes which it was possible to introduce in the activities of the Division at the conclusion of the war have resulted in a more balanced programme of work than has been practicable in previous years. The amount of routine testing and calibration has fallen to proportions which can be readily handled, and much of the outstanding work necessary to place the standards for which the Division is responsible on a sound basis has now been done. It must be expected that the Division will always have to spend a considerable portion of its time on the maintenance of standards, developmental investigations connected with standards, measurements in terms of the physical units represented by or derived from these standards, and on *ad hoc* investigations of direct assistance to industry. It is considered, however, that at least half the time of the scientific staff of the Division should be available for physical research. Something approximating to this balance now obtains.

The principal standards maintained by the Division are those of temperature, electrical current and electrical potential, and the photometric standards. The maintenance of all these standards is now in a fairly satisfactory state, although further, less urgent, work remains to be done in connexion with some aspects of them. The standard of temperature, the International Temperature Scale, was realized at the the formation of the Laboratory in terms of equipment calibrated by the National Physical Laboratory, England. The policy has always been adopted that this standard should be maintained, not as a transfer standard, but as one fully realized in the Division. The work necessary to achieve this is now almost complete. The electrical and photometric standards are realized in terms of the corresponding standards maintained at the National Physical Laboratory. The accuracy with which the electrical sub-standards can be calibrated at that Laboratory is such that it seems certain it will never be necessary to set up in Australia the complex equipment required to realize the basic standards.

Although the situation is not quite so satisfactory regarding the photometric standards, their nature is such that, hitherto, it has been impossible to realize them in any other way than by the use of secondary transfer standards. On 1st January, 1948, a different unit of candle-power will be introduced, the "New Candle", which it will be possible for any laboratory to realize. It is thought that, at some time in the future, it will be desirable for the equipment for the realization of this unit to be set up in the Division. Preliminary steps have been taken in this direction.

During the year investigations referred to in previous reports have been continued. These include studies in hygrometry, spectrophotometry, solar physics, and the physics of wool fibres. The X-ray diffraction equipment constructed in the Division has been brought into operation. Three new major projects have been commenced: (*a*) the setting up of equipment for research at very low temperatures, (*b*) laboratory investigations connected with the artificial production of rain, and (*c*) the absolute measurement of ultra-violet spectral energy distributions with a view to determining solar energy distributions. As in previous years, numerous requests have been received from other Divisions of the Council for assistance in the design and construction of equipment to meet special requirements.

Lack of accommodation is being overcome by building extensions, which will also allow a better grouping of the laboratories in their Sections.

The Division is represented on several committees of the Standards Association and has, as heretofore, tendered advice and assistance to industry on many problems. During the year 264 certificates, reports, and statements of examination were issued giving the results of tests and calibrations made by the Division. As in previous years, a short course of lectures and demonstrations has been given to senior physics students of the University of Sydney.

The Chief of the Division, who went overseas in May, 1946, as Scientific Adviser to the Australian Delegate on the Atomic Energy Commission, United Nations Organization, resumed his duties in February, 1947. At the request of the Department of External

Affairs he went overseas again in April to attend further meetings of the Atomic Energy Commission in the same capacity as before.

2. *Heat.*—(i) *General.*—The Heat Section, more than any other section in the Division, is called upon to undertake calibration and test work for industrial and scientific purposes. The work associated with the development and maintenance of the International Temperature Scale and the calibration of temperature measuring equipment in terms of this scale is considerable but is, as far as possible, organized in such a way as to leave the scientific staff ample opportunity for research.

Investigations on humidity control and measurement have been continued, and the facilities built up for this type of work, together with the extensive experience of officers of the Division in temperature measurement, have been applied to the investigations which have been commenced on the formation of ice crystals. These investigations are part of a joint project with the Division of Radiophysics on the artificial production of rain.

Plans have been made for the initiation of physical research at temperatures approaching absolute zero—a very promising field for investigation. The necessary equipment is at present under construction and, as an adjunct to this project, a liquid-air unit has been purchased.

(ii) *International Temperature Scale and Temperature Measurement.*—The realization of the International Temperature Scale in the range of temperatures for which it is defined, from —190° C. upwards, involves the establishment of equipment to realize seven fixed points, and the use of these to calibrate, for their respective temperature ranges, standard resistance thermometers, thermocouple pyrometers, and optical pyrometers. Although the International Temperature Scale has been realized in the Section with an accuracy which is sufficient for most purposes, further improvements are necessary if all requirements for precise temperature measurement are to be met. Equipment calibrated in terms of the temperature scales maintained at the National Physical Laboratory, England, and the National Bureau of Standards, United States of America, is to hand, and comparisons between the scales of these laboratories and that maintained here are planned.

Actual calibrations are rarely made directly in terms of the standards with which the temperature scale is realized, secondary standards usually being used. In the range —190° C. to 500° C. these take the form of liquid-in-glass thermometers. Sets of thermometers calibrated at the National Physical Laboratory were used as transfer standards for calibrations in this range of temperatures until the standard scale had been independently established. Although satisfactory as a temporary measure, these could not be relied upon indefinitely without re-calibration, and were in many cases not calibrated to an accuracy sufficient for all industrial needs. Most of these sub-standards, together with additional ones, have now been directly calibrated against the standards of the Division.

Equipment for the comparison of thermometers has been augmented by the construction of several new comparison baths. These include a water bath suitable for the calibration of deep-sea reversing thermometers, an improved salt bath, and a cryostat for use at temperatures down to —190° C.

For the measurement of high temperatures, the disappearing filament optical pyrometer is the standard instrument. A new instrument of this type, incorporating numerous improvements on that previously used, has been designed and constructed. An optical pyrometer frequently suffers from the disability that its filament does not appear of uniform brightness and consequently cannot be made to disappear completely against the background of the hot body on which it is sighted. To overcome this trouble, the visual aperture of the instrument is often reduced, although this reduces the accuracy of the instrument and restricts the range of temperature over which it can be used. Investigations by the Light and Heat Sections have revealed that the disappearance of the filament may be much improved by including a suitably orientated polarizing screen in the eye-piece, thus permitting the use of large apertures and the attainment of improved accuracies.

In using a thermocouple to measure temperatures, one end of the thermocouple wires, usually known as the reference junction, must be maintained at a known temperature. Melting ice is frequently used for this purpose. For many laboratory and field applications it would be advantageous, however, to use some substance which has a melting point a few degrees above ambient temperature. The possibility of using diphenyl ether, which has a freezing point of approximately 27° C. is at present being investigated and indications are that this material, if pure, will give a reference junction temperature which can be relied upon to better than ±0.05° C.

The Section has continued to provide a service in industrial pyrometry similar to that rendered to the Ministry of Munitions during the war, but on a much reduced scale. This involves the checking of pyrometric equipment and furnace installations for industrial organizations and the calibration of working standards for temperature measurement for other establishments.

The development of facilities for the attainment of temperatures down to 2° K. will extend the range of temperatures realized within the Division to far below the present lower limit of the International Temperature Scale. Measurements will, in this case, be made on the scale on which the International Temperature Scale is based, the Thermodynamic Scale. Techniques for temperature measurement which are new to the Section will require to be developed. These techniques will later find application to measurements on the International Temperature Scale if, as is anticipated, this scale is extended to lower temperatures.

(iii) *Special Devices for Temperature Measurement and Control.*—As in previous years the Section has received numerous requests for advice and assistance in the solution of unusual problems in temperature measurement or control, many of these requests arising within the Council. The design of equipment to record sea-water temperatures at various depths automatically, methods of measuring stored energy in metals, and development of elements suitable for measuring temperatures up to 250° C., to an overall accuracy of ±0.01° C., in a situation in which only 2 cm. immersion is practicable, are cases in point.

Mention has been made in an earlier report of an electronic controller developed in the Section which has been found particularly useful for the accurate control of temperatures in liquid or air baths and, in a modified form, for the control of humidity. With this instrument the temperature of a stirred water bath can be maintained constant to better than ±0.001° C. Numerous requests have been received for information regarding the design of this equipment, which has proved so useful in the Section that five such units have now been constructed. One of these has been applied to the control of the temperature of the bridge used for measurements with resistance thermometers.

A photoelectric galvanometer amplifier for the measurement of very small voltages has proved particularly useful for the measurement of small temperature differences with thermocouples; it also has many other research applications. It can be used to measure an e.m.f. of 10 microvolts with an accuracy of ±0.01

microvolt (corresponding in the case of a thermocouple, to about ±0.0002° C.) and can be directly coupled to a voltage recorder when a record of its readings is desired.

(iv) *Hygrometry.*—Much of the work on hygrometry has, in the past, been directed towards the solution of immediate problems arising in connexion with tropicproofing. With the virtual cessation of this work the opportunity has been taken to collate the information gained and to undertake additional work to supplement this information, several interesting lines of investigation having arisen from the earlier work. Sporadic attention continues to be given by the Divisions of Electro-technology and Physics to the question of specifications for the tropictesting of telecommunication equipment, particularly to attempts to unify the specifications of Great Britain and Australia.

The electronic humidity controller, which was developed for the close control of the high humidities used in tropicproofing tests, has now been applied to the control of lower humidities with equally satisfactory results. The equipment is very versatile and could undoubtedly be applied with success to the control of humidities by quite different methods from those with which it has as yet been used. It would seem to have potential industrial applications. A theoretical analysis, checked by experimental tests, has been made of the nature of the temperature or humidity control obtained with systems such as those which have been used, particular attention having been given to the factors which determine whether a system subject to proportional control will maintain steady or regularly varying conditions.

Arising out of the use of thermocouple psychrometers for the measurement of humidity, a detailed investigation of the basic laws governing the mode of operation of the psychrometer (wet and dry bulb hygrometer) has been undertaken. The problem has been investigated both theoretically and experimentally, particular attention having been given to the relationship between the temperature depression of a psychrometer and both the diameter of the wet element and the air movement past it. The results already obtained cast doubt on the validity and practical usefulness of many of the results obtained by earlier workers.

An automatic dewpoint hygrometer is in course of construction. In this instrument the formation of dew on the test surface will be detected photoelectrically and the current from the photocell used to control the temperature of the surface. By fitting a special optical system to a visual dewpoint hygrometer, so that light is multiply reflected from the surface on which the dew forms, it has been possible to increase markedly the sensitivity of the instrument.

(v) *Thermal Conductivity.*—Although requests for the measurement of the thermal conductivity of insulating and other materials are received from time to time, measurements of this type are of such a routine nature that the Division has been reluctant to set up facilities for this work. However, it has undertaken to assist the Council's Section of Building Materials Research, which requires to be able to measure the thermal conductivity and thermal transmissions of building materials in establishing the necessary facilities; to this end there is under construction an equipment, designed in the Division, which will be suitable for tests on 12 in. by 12 in. specimens at low and ambient temperatures. The design of an apparatus for the measurement of the thermal transmission of 4 ft. by 4 ft. wall sections has been completed, this apparatus being also intended for use by the Building Materials Research Section.

(vi) *Ice Crystal Formation.* — Investigations of methods of artificially inducing moisture precipitation (rain or snow) were initiated during the war by the Division of Radiophysics; the Division of Physics has, from the outset, co-operated in some aspects of this work and has concentrated on laboratory investigations of the physical phenomena involved. The process of ice crystal formation in fogs of super-cooled water droplets is being intensely investigated, particularly in relation to the methods of initiating crystal growth. The two methods studied have been (*a*) that of causing minute ice crystals to form in the fog by locally cooling regions in the fog with cold bodies (e.g. small pieces of solid carbon dioxide), and (*b*) that of introducing into the fog crystals of foreign substances on which ice crystals will form. Once ice crystals have been formed in a fog or cloud of supercooled droplets, they will grow at the expense of the droplets, and under natural conditions may ultimately fall to the earth as snow or rain.

The investigations of the Heat Section on method (*b*) have included observations of the effect of the temperature of the cold body and the temperature of the fog on the nature of the ice crystal formation, and of the rise of temperature in the fog due to the latent heat given out in the formation of ice. Investigations on various substances which might be suitable for use in the formation of rain by method (*b*) have included observations on the relative efficiencies in ice crystal formation of a number of different substances, the maximum temperatures at which they are effective, and the best methods of forming and dispersing the foreign crystal nuclei. It has been found that some substances are particularly effective; as small a quantity of silver iodide as 10^{-15} g., dispersed as a smoke, is sufficient to fill a 30 cu. ft. chamber with a dense fog of ice crystals.

The process of crystal formation is visually quite spectacular, and a film of some aspects of the work has been prepared. In order to study the phenomena under more closely controlled conditions than is possible in a large chamber, a small expansion chamber has been prepared. In order to study the phenomena rooms of the Division of Food Preservation have also been commenced; under these conditions both the experimenter and his instruments are in the region of crystal formation and investigation of the phenomena of crystal growth is thus simplified.

(vii) *Low Temperature Physics.* — There are in Australia at present no facilities for research at very low temperatures. Measurements made at these temperatures are of considerable significance in relation to fundamental physical theories, particularly in the physics of the solid state, including magnetism, electrical conduction, and heat conduction. Determinations of the thermodynamic properties of certain types of chemical substance also require measurements at low temperatures; these properties are of importance for the prediction of chemical reaction rates.

The provision of facilities for attaining low temperatures and the initiating of physical research at these temperatures is a natural development of the work of the Heat Section, and to this end equipment is at present under construction in the laboratory workshops. The equipment being built is in the form of a cryostat capable of maintaining any temperature down to about 2° K. in its working space. It can, in addition, be used for the liquefaction of any gas. The design is similar to one developed at the Massachusetts Institute of Technology, and represents a considerable advance over the more classical types of low temperature equipment, particularly in respect of its simplicity, compactness, and low initial and running costs.

The setting up of low temperature equipment will further extend the Section's facilities for temperature measurement and standardization, and will ensure that

there is in the Division a group knowledgeable in low temperature engineering, a field likely to become of industrial importance.

Partly as an adjunct to the low temperature project, an oxygen generator has been acquired; it is being modified for use as a liquid air generator and may later be further modified to allow of its use for the production of liquid nitrogen. It is anticipated that the unit will be capable of delivering 30 litres of liquid air per hour.

3. *Light.*—(i) *General.*—Further attention has been given in the Light Section to many of the projects referred to in the last Annual Report and, in addition, work has been initiated on several new projects. One of the important functions of this Section is the maintenance of the photometric standards. The position regarding these standards has been considerably clarified by an extensive series of intercomparisons between the standard lamps held by the Division.

A knowledge of the ultra-violet emission of the sun is of importance in the fields of solar and terrestrial physics, and in view of the particularly suitable facilities and experience of the Section, work has been commenced on an investigation along these lines.

As in other years, the Section has been called upon to advise and assist in the design and construction of special optical and photometric instruments for use in other establishments, particularly other Divisions of the Council.

(ii) *Photometric Standards.*—The photometric standards maintained by the Division are those of horizontal candle-power, luminous flux, and colour temperature. These standards are realized by means of sets of lamps which have been calibrated to sub-standard accuracy at either the National Physical Laboratory, England, or the National Bureau of Standards, United States of America. The use of transfer standard lamps to establish the photometric units in Australia is necessary because the International photometric units have, up to now, been based on actual lamps held by the main standardizing laboratories of the world. The use of transfer standards will no longer be necessary after 1st January, 1948, when a new unit of luminous intensity will be introduced. This unit, to be known as the "New Candle", will be defined by reference to the luminous intensity of a black body at the melting point of platinum. While the Division does not propose, in the immediate future, to depart from its practice of basing its units on sub-standard lamps calibrated at the National Physical Laboratory, and will always use such lamps for the comparison of the units as realized here and elsewhere, preliminary consideration has been given to the acquisition of some of the equipment which will be necessary for the full realization of the unit of luminous intensity.

The accuracy and constancy of the sub-standard lamps used to establish the various photometric units are checked by intercomparisons between lamps, including checks against lamps which have recently been calibrated at the National Physical Laboratory or the National Bureau of Standards. In making such intercomparisons, may of the errors present in visual photometric observations can be avoided by the use of properly corrected photoelectric cells, a procedure which has been adopted in the measurements mentioned.

The results of the intercomparisons of the lamps used to establish the unit of luminous intensity are in very satisfactory agreement with the calibration figures of the National Physical Laboratory, the average relative difference being less than ± 0.2 per cent. The agreement between the lamps used to establish the unit of luminous flux does not seem to be quite so satisfactory, although the measurements on these lamps are not yet complete.

Visual intercomparisons of colour temperature sub-standard lamps have also been made, and the results obtained indicate that the lamps agree among themselves to within about 10° K.

(iii) *Spectrophotometry.*—In the last report mention was made of the installation of a General Electric automatic recording spectrophotometer. During the year considerable use has been made of the excellent facilities this instrument provides for the rapid measurement of spectral reflectances or transmissions, in all some 800 curves having been produced with it. Uses to which the instrument has been put have included measurements of paper reflectances and of the colours of foodstuffs and sugar-phenol complexes; a study of the cyanide compounds of haem and haematin; investigations into the colorimetry of vanadates; and the development or calibration of special filters for optical pyrometry, the visual colorimetry of chlorophyll, stellar photometry, and heterochromatic photometry. The rapidity with which a spectrophotometric curve on a sample can be made (3 minutes) has proved particularly advantageous in several investigations of unstable chemical substances.

(iv) *Haemoglobinometry.*—A photoelectric haemoglobinometer designed and constructed in the Section has now been in routine use in the Red Cross Blood Bank for several years, and an Australian instrument-maker has undertaken commercial production of the instrument. The Division has agreed to calibrate these instruments, and to this end has measured the spectral transmissions of oxyhaemoglobin solutions, standardized and supplied by Dr. H. S. H. Wardlaw, Senior Pathologist of Sydney Hospital. At the same time an investigation was made of the stability of the absorption properties of oxyhaemoglobin and acid haematin solutions.

(v) *Colorimetry.*—While the requests received for colour determinations are now fewer than they were during the war, there appears to be a real need in industry for a satisfactory colour-measuring intrument. To satisfy this demand a photoelectric tri-colorimeter suitable for a wide range of industrial or scientific color measurements is being designed. The design, which is nearing completion, is based on the experience already gained with two somewhat similar experimental instruments previously developed in the Section.

(vi) *Ultra-violet Spectral Energy Distribution.*—Work has been commenced on a project having as its ultimate object the determination of the spectral distribution of energy in the light radiated by the sun in the far ultra-violet, and having as its immediate object the development of facilities for measurement and investigation in the far ultra-violet. The long-term project involves the development and calibration of a spectrograph for the measurement of ultra-violet spectral energies and the projection of this instrument, in a rocket, into the upper atmosphere, where the solar measurements would be made.

Attention has naturally been concentrated, in the first place, on the laboratory side of the investigations; these involve numerous scientific and technical problems, most important of which is that the absorption of very short wavelengths is so great for almost all known substances, including air, that the source and measuring instrument must be enclosed in the same evacuated chamber. A one-meter grating vacuum spectrograph which includes as a spectral feature the facility to use a photographic plate, bolometer, or photoelectric cell as the energy detector, has been designed. It is proposed that the gratings for use with this instrument should be ruled on the Grayson ruling engine in the Division of Metrology. The calibration of the spectrograph will require the use of a stable ultra-violet source of high intensity, and

as a first step towards the development of a suitable source a discharge tube giving a bright continuous spectrum down to 2,000 A. has already been constructed.

(vii) *Measurement of Radiant Energy.*—Notable advances have been made overseas in recent years in techniques for the detection or measurement of very small quantities of radiant energy. By using a detector of very quick response and by interrupting the beam incident on it, its output can be amplified by standard electronic methods; as a result, an assembly of very high sensitivity is obtained. A number of experimental evaporated metal film resistance bolometers, and a suitable amplifier, have been made up with a view to using these techniques in the measurement of ultra-violet energy. Results so far are promising, although the work is still in the developmental stage.

Another technique which has been applied to the measurement of small amounts of radiant energy has been the use of multiplier photo-tubes, and the improvement in the performance of these tubes at liquid-air temperatures is being investigated.

A capacity-type evaporated metal film bolometer is being developed, in co-operation with the Division of Radiophysics, for measurement of energies in the millimeter wavelength band.

(viii) *Thermal Reflectances.*—Many cases arise in which the heat transfer across a barrier is determined more by the radiative properties of the materials comprising the barrier than by their thermal conductivities. This is so in some forms of building insulation, particularly roof insulation, where thin sheets of materials of low emissivity are used to reduce the low temperature radiative heat transfer. Equipment has been set up with which the diffuse thermal reflectance of a material to the black-body radiation of a source at 100° C. can be measured, and measurements have been made on a number of test samples.

(ix) *Distribution of Light Intensity Across an Optical Image.*—A theoretical analysis has been completed of the distribution of diffracted light at the image of a source of finite width when the source emits light uniformly in all directions. This analysis has application to a number of optical problems. Different conditions arise when an image is formed of an object illuminated by light which is restricted in direction, a case which frequently occurs in optical instruments. The distribution of light in the image under such conditions is now being investigated.

(x) *Film Projector Tests.*—In order to provide a means of critically assessing the performance of 16 mm. sound and film projectors, and to assist local manufacturers of these units, the National Standards Laboratory undertook, in 1945, to test prototype units of local manufacture and, for comparison purposes, to make tests on some imported instruments. The co-ordination of this work, which was undertaken at the request of the National Films Board, has been the responsibility of this Division; all three Divisions of the National Standards Laboratory have co-operated in the work. Tests have now been completed on machines of seven different makes, two of local and five of overseas manufacture. It is understood that two further instruments, one of local assembly but incorporating many imported components, and the other of wholly local manufacture, will soon be submitted for test. The survey of the locally produced machines will then, for the time being at any rate, be complete. The standard attained by the locally made units is very encouraging, although in some respects it is not up to that of the best instruments of overseas manufacture. Ways in which the units could be improved have been suggested.

Recently a further request has been made by the National Films Board that tests should be made on 35 mm. strip film projectors; suitable testing specifications are being prepared.

(xi) *Evaporation Plant.*—The equipment set up for the evaporation of metals and other substances on to surfaces has been used extensively during the year, principally for the production of aluminium reflectors and semi-reflectors, although other metals, such as silver, antimony, and nickel, have also been evaporated onto glass to produce reflectors. The convenience with which aluminium reflectors can be produced, and their satisfactory properties, have largely eliminated the use of silvered reflectors (produced by chemical means) in the laboratory. The plant has also been used for the deposition of "non-reflecting" magnesium fluoride films on glass surfaces, the production of thin metal film bolometers, and the evaporation of antimony to form a black absorbing surface.

(xii) *Optical Workshop.*—The optical workshop, which provides valuable facilities for the production of high quality optical components, flats, and filters, has continued to meet all the calls made upon it, not only for the work of the Division but also for other Divisions of the Council.

During the year the facilities have been further improved by the addition of a precision lens edging machine and centring attachment, both of which were designed in the Division and constructed in the laboratory workshops. The centring attachment incorporates novel features which make for simpler and quicker centring adjustment than is possible with the more usual attachments.

4. *Solar Physics.*—It has already been reported that a possible explanation for the occurrence of chromospheric flares on the sun has been formulated in terms of the influence of a growing sunspot on the solar atmosphere surrounding the spot. The theoretical analysis of these effects has now been developed in much greater detail, account having been taken of additional factors not considered in the theory as it was first outlined. In particular, consideration has been given to the manner in which the propagation through the solar atmosphere of the magnetic field due to the sunspot is affected by the anisotropic conductivity of this atmosphere, and to the magnitudes of the resulting electric field and currents to be expected. The theory of the origin of chromospheric flares has now been developed to a stage at which it has been possible to deduce most of the important observed features of these flares.

From a consideration of the motion of charged particles in the sun's atmosphere in the vicinity of a growing sunspot, it has been shown that, in certain circumstances, and in isolated locations, equal and uniform upward velocities of the order of 100 km. per sec. can be acquired by both positive and negative particles. This phenomenon is proposed as the mechanism responsible for the expulsion of certain types of prominence from the chromosphere.

5. *The Physics of Solids.*—It was reported last year that the nucleus of a Section to undertake work in the field of the physics of the solid state had been established within the Division. Progress in the development of this Section has not been as great as had been hoped, principally because of the difficulty of obtaining scientific staff experienced in this branch of physics, and partly because of unexpected delay in the completion of the X-ray diffraction equipment for use in the Section. Throughout the first nine months of the year, the Division had the assistance of an officer of the Broken Hill Proprietary Company Limited, appointed for work on this project, and several problems of interest to the company were investigated by this officer, using X-ray diffraction methods.

The X-ray diffraction equipment designed in the Division and constructed in the laboratory workshops, is now virtually complete. It makes use of a continuously evacuated X-ray tube with which four cameras can be used simultaneously. The equipment has been assembled in a temporary form and found to operate satisfactorily, and is now in process of being mounted permanently in one of the laboratories in the new wing of the building.

6. *Wool Investigations.*—(i) *General.*—The results of the investigations on wool structure by the Section of Wool Physics would seem to have important implications regarding the form of the keratin molecule. The Light Section has made a microphotographic study of the migration of fibres during felting and has also given further attention to the development of special instruments for measurements on fibre diameters; the Heat Section has continued its study of electrical methods of measuring moisture content.

(ii) *The Structure of the Wool Fibre.*—It was reported last year that two components had been distinguished in the cortical cells of the wool fibre, one with the longitudinally aligned fibrils and the other with the amorphous matrix in which the fibrils are embedded. During the year these components have been examined in greater detail with the electron microscope, using the gold-shadowing technique. The rather surprising result has been obtained that both components appear to consist of approximately isometric particles, whose linear dimensions are of the order of 100 Angstrom units. The size of the particles is such that they may well be molecules of keratin. This new information is obviously of considerable importance and re-opens the question of the form of the keratin molecule, which is a polypeptide chain and has generally been held to be long and thin, even when regularly folded. In the amorphous matrix from the cortex of the fibre these particles are distributed at random; in the fibrils, they are lying like beads on a string, the different strings being slightly twisted around each other. This twist accounts for at least some of the dispersion shown on X-ray diffration photographs previously obtained. The investigations have been carried out as a joint project with the Division of Industrial Chemistry.

(iii) *Frictional Properties of the Wool Fibre.*—The measurements already made on the frictional properties of textile fibres, particularly wool fibres under various conditions, have been further extended and analysed. The frictional asymmetry of the wool fibre, which is regarded as the cause of felting, has been ascribed by different workers to two different causes, one school considering that it is due to an asymmetry of the molecular fields at the surface of the fibre, and the other that it is due to the geometrical shape of the scaly surface of the cuticle—a ratchet-like effect. An analysis has been made on a semi-quantitative basis of the implications of this ratchet theory, taking into account the actual geometrical form of the scales and their resistance to deformation. Using the expressions obtained from this analysis, it has been possible to explain in terms of this theory many observations which were formerly considered to be incompatible with it.

Interesting information on the process of felting has resulted from some work done by the Light Section, in which the actual migration of individual wool fibres has been recorded in a series of microphotographs taken as felting proceeds. There can be no question that the felting process is one of tangling produced by the rootward movement of the individual fibres relative to the other fibres present. The different migrational behaviours of normal fibres and fibres which have been submitted to shrinkproofing treatments is clearly revealed.

In addition to the measurements made on wool, measurements have also been made of the frictional properties of a number of other fibers—animal, vegetable and artificial. Included in these are some preliminary measurements, made on behalf of the Flax Research Section, of the coefficient of static friction of flax on flax. The results obtained, although not conclusive, seem to suggest that there is some correlation between the coefficient of friction and the grade of the flax, a low coefficient of friction, permitting of a high pull-out in drafting, corresponding to a high grade of flax. More detailed work is contemplated when the Flax Research Section has been able to investigate more fully the relationship between the grade of flax and its spinning properties.

(iv) *Fibre Metrology.*—Attention has been given in the Division for some time to the development of special equipment to assist in the measurement of the physical characteristics of wool fibres, particularly fibre diameters. The light Section has designed an instrument, operating on photometric principles, with which the mean diameter of the fibres in a bundle may be determined without having to resort to the tedious and time-consuming method of making measurements on each individual fibre. The original model was found to work very satisfactorily and three further instruments, of the same general design but better suited to routine work, are under construction for the Fleece Analysis Laboratory and other laboratories of the Council.

The fibre diameter meter gives only the mean diameter of the fibres in a bundle. The coefficient of variation of the diameters of the fibres is another important characteristic of wool samples. It has been shown mathematically that if, in addition to the mass and the cross-sectional projected area of a wool sample, the total fibre-length is known, both the mean diameter and the coefficient of variation of the sample can be determined. With wool, however, the accuracy with which the coefficient of variation can be measured by this method is not sufficiently great to be useful. The above analysis has brought to light a factor which seems to have been overlooked in fibre metrology, namely that if the fibres are of non-circular cross section, the coefficient of variation, as usually measured, will include a component due to the eccentricity of the cross section. Although the component is negligible for most types of wool, it may become significant when measurements are made on fibres of unusual cross section.

The optical diffraction pattern produced by a uniform fibre when placed in a light beam varies with the fibre diameter. It follows that the diffraction pattern from a bundle of fibres of different diameters is related to the distribution of diameters of the fibres, and an investigation has been made in the Light Section of the possibility of using this phenomenon to determine, by simple measurement, the coefficient of variation in such a case. The method shows some promise; however, the fact that the quantiay measured is a function of the whole distribution of diameters of the sample and not of just the coefficient of variation sets a limitation to the accuracy of the method. This limitation has been found to be significantly important with wool samples. The equipment developed for the measurements has been given to the Fleece Analysis Laboratory for a further investigation of its practical usefulness.

For many measurements on wool it is important to know the moisture content of the fibres. This is usually determined by a gravimetric method, which, since it involves drying the sample, is time-consuming. The Heat Section has constructed an instrument with which the dielectric properties of a sample of wool can be measured, with a view to testing its applicability to the instantaneous determination of the moisture content of wool samples. It is somewhat similar to an

instrument developed at the National Physical Laboratory, England, for the measurement of the moisture content of grain. The results so far obtained have been promising, and it is proposed to pass the instrument to the Fleece Analysis Laboratory for a fuller investigation of whether there is a sufficiently close correspondence between the electrical properties and the moisture content of wool to permit the use of the instrument for routine moisture content measurements.

7. *Atomic Physics.*—Throughout the greater part of the year an officer of the Division has continued to work in the Vacuum Physics Laboratory of the Division of Radiophysics, as part of the group concerned with the development of equipment for the linear acceleration of elementary particles to high velocities. He has been concerned with (*a*) theoretical and experimental investigations of the operating conditions for the linear acceleration of protons by pulse methods; (*b*) the design of a proton source for use with the accelerator; and (*c*) the design and construction of a mass spectrograph leak detector.

Some attention has been given to the construction of apparatus for the detection of single nuclear particles. Boron trifluoride chambers for the detection of neutrons have been designed and placed under construction, and a linear amplifier has been constructed for use with these counters and with counters suitable for detecting protons and alpha-particles. Mica-window Geiger-Müller counters suitable for detecting low energy beta-particles, and the associated electrical counting circuits have been supplied to the McMaster Animal Health Laboratory for use in work with radioactive tracer elements.

8. *Publications.*—The following papers have been published during the year:—

Giovanelli, R. G. (1946).—A theory of Chromospheric flares. *Nature* 158: 81.

—— (1946).—Welding and the eyes. Accident Prev. Bull. 3, Spec. Suppl., p. 5.

Makinson, K. Rachel (1947.—The physical properties of wool. *Aust. J. Sci.* 9: 199.

Makinson, K. Rachel, and Mercer, E. H. (1946).—The mechanism of the frictional difference of wool fibres. *J. Text. Inst.* 37: T180 (letter).

Mercer, E. H., and Rees, A. L. G. (1946).—An electron microscope investigation of the cuticle of wool. *Aust. J. Exp. Biol.* 24: 2.

Mercer, E. H., and Rees, A. L. G. (1946).—The structure and elasticity of the cortex of keratin fibres. Ibid. 24: 175-183.

Farrant, J. L., Rees, A. L. G. and Mercer, E. H. (1947).—The structure of fibrous keratin. *Nature* 159: 535.

XIV. AERONAUTICAL INVESTIGATIONS.

1. *General.*—The past year has seen important developments in the field of aeronautics which affect the Division to a greater or lesser extent. One of these is the phenomenal growth of civil aviation in Australia. Statistics show that on a population basis Australia uses air travel almost as much as the United States of America and air freight even more—a truly remarkable record.

On the service side comparatively little change has occurred during the year. This also applies to the aircraft industry with one exception—the decision to manufacture locally the "Vampire" jet-propelled fighter. Actually, the rather static state of service aviation and the production industry is of some benefit to the Division. It has caused a falling-off in the amount of *ad hoc* work, and has thus enabled greater effort to be concentrated on the fundamental and long-term research projects.

In this connexion, an event of particular importance to the Division was the holding in London of the first Commonwealth Aeronautical Research Conference, attended by delegations from the United Kingdom and Dominions. The basic aim was to set up some mechanism for the co-ordination of aeronautical research throughout the British Empire. It has long been realized that, as aeronautical research covers such an extensive field and requires such large resources in man-power and finance, the best results within the Empire would be achieved by co-ordinating the activities of the research groups in the United Kingdom and the Dominions. The foundation for this co-ordination was laid and certain important projects were allocated to Australia.

Even with this co-ordination and the consequent narrowing of fields of research, it was realized that the Division could not hope to cover more than a small part of the potential field, and so an endeavour was made to widen the scope of the work by interesting other organizations in suitable projects. The University of Sydney in its Department of Aeronautical Engineering already has an active research team, and this has been strengthened by aditional research staff appointed by the Council. A small beginning has also been made with the University of Melbourne at which a research student has been appointed to work under the Professor of Mathematics on certain problems of compressible flow. The Munitions Supply Laboratories too, through the Engineering Group Committee, have undertaken work on fatigue which will dovetail into the structures programme of the Division.

During the year the Australian Council for Aeronautics was disbanded. It was considered that the terms of reference of this Council were too wide and that, as an independent committee unattached to any particular Government department, its recommendations were difficult to implement. Consequently, it is to be succeeded by a committee which by its terms of reference will be limited to aeronautical research matters on which it may be freely consulted by any organization requiring advice, though for departmental procedure this committee will be attached to the Council.

Difficulties continue to be met in regard to staff. Many attractive positions are offering in industry and in the expanding field of civil aviation, and it is difficult to retain experienced men. In addition to staff shortage caused by resignations, the end of the war has given an opportunity long denied to those who wish to enlarge their research experience or to undertake advanced studies abroad. No less than ten officers of the Division are at present overseas, the majority having been granted fellowships or studentships from Commonwealth or overseas sources.

2. *Structures.*—(i) *Theory of Structures.*—In modern aircraft high structural efficiency is achieved by making the outer surfaces forming the aerodynamic shape carry a large proportion of the structural loads. In such stressed skin construction the load-carrying surface is effectively divided into a number of panels or plates, some flat and some curved in one plane. Individual panels, or the whole shell when subjected to compressive loads, usually fail by buckling before the ultimate strength of the material is reached.

Two major questions are involved in the design: firstly, the stability, i.e., the load to cause buckling and the capacity to carry load after buckling and secondly, the structural efficiency which aims at the optimum distribution of material between stiffeners and skin. On both these subjects a good deal of work has been done.

(*a*) *Stability of plates and shells.*—The initial buckling loads are given with sufficient accuracy by "small deflection theory", and a very exhaustive

analysis of the behaviour of flat plates has been made. This covers both isotropic and orthotropic materials so that metal, plywood and sandwich constructions can be treated. A number of reports covering experimental and theoretical work have been published, and a comprehensive report has been prepared summarizing all available theoretical knowledge for dealing with any type of rectangular flat plate under edge forces. The approximate theoretical solutions for curved plates have not been satisfactory, but an extensive experimental investigation of curved plywood panels has provided empirical data of the greatest value.

After buckling, the deflections are large and the behaviour cannot be satisfactorily predicted by small deflection theory. Much work on large deflection problems has been done, but the theory is extremely difficult and progress has been disappointing. The method first used involved the solution of systems of equations in infinitely many unknowns. In view of the difficulties of the method a review of the literature is being made to assess the applicability of other methods such as, for example, non-linear membrane theory, or the transformation of the differential equation problem to a variational problem.

(*b*) *Structural efficiency of stiffened plates and shells.*—The aim of this work is to arrive at the structure of the smallest weight which, of given outside dimensions and materials, will carry a specified system of loads. A necessary preliminary to any such analysis is to be able to predict accurately the behaviour of any structural element when loaded, and a comparative study has been made of the methods of predicting the strength of flat and curved stiffened plates in end compression.

An analysis is being made of stiffened cylinders representative of fuselage construction in order to determine the structure of minimum weight. A series of cylinders in which radius, skin thickness, stiffener size, and ring size vary has been examined and the envelope of the least weight curves obtained. An attempt is now being made to find a stiffener and ring spacing which will give the lightest cylinder of given radius and moment of resistance. It was found that, when the sheet thickness was increased and the number of stiffeners reduced, different design methods gave increasingly divergent results. These discrepancies are being investigated.

(*c*) *Open sections in compression and bending.*—The stiffeners used in stressed skins are usually thin metal open sections such as channel and Z sections. Their design for compressive and bending loads presents difficult problems. A study of the strength and stability of these shapes including a comparison of design methods was therefore made. The work is being written up in concise form for use in an ordinary design office, because sections are used as structural elements in many engineering fields including building construction.

(*d*) *Grid panels and panels for housing.*—During the war years a novel form of construction was evolved in the Division firstly for light-weight floors for aircraft and later for the main structure. The theory for the design and analysis of grid panels in compression was confirmed by a series of experiments and has been extended to deal with shear loads and loads normal to the surface of the panel. Preliminary work on grid cylinders partially and completely covered with skin has commenced and analytical solutions obtained for bending actions.

The grid panel form of construction effected appreciable savings in the weight of floors in Australian civil aircraft converted from military transports and, proceeding from the same ideas, a form of prefabricated building panel was devised. This consists of two asbestos cement sheets separated and stabilized by a light wooden grid to which the sheets are glued with a special synthetic resin adhesive.

The chief advantages of this type of panel are that it can carry all structural loads without additional framing; the quantity of timber required for the grid is relatively small, no large sizes of timber being needed; standard panels can be used for walls, roof, and even for the floor; and it provides a good measure of heat insulation. This form of construction has been taken up enthusiastically by a Victorian manufacturer, and panels for several hundred houses have already been supplied to a State Government department at a present production rate of more than ten houses per week.

(*e*) *Design and analysis of wooden box spars.*—An investigation which has extended over the last eight years has now been completed. After extensive experimental investigations in which over 300 spars of differing proportions and materials were tested, four hypotheses were advanced regarding the stress distribution in box spars at failure. Each of these was examined in the light of the experimental data, and the hypothesis which most nearly fitted the observed facts was accepted. Using these results, data for design purposes have been prepared in the form of semi-empirical curves which enable the most suitable spar for any given conditions to be determined directly.

(ii) *Effect of Temperature on the Strength of Aircraft.*—An operational problem is raised by the possibility that the strength of wooden aircraft under tropical conditions is reduced, and at the request of the British Ministry of Supply an investigation on the strength of actual components was made. Tests carried out at Alice Springs and in Northern Queensland showed that when aircraft were parked out in the open surface temperatures up to 100° C. were likely in summer. Laboratory tests were therefore made on a number of wooden tailplanes in which the effect of strong sunlight was simulated by radiation from infrared lamps. The tailplanes were conditioned to an approximately constant moisture content and some were tested at normal temperature (about 20° C.) while others were subjected to radiation during which the upper surface temperature had risen to 80° C. before testing. The results showed that the effect of the heat was to reduce the strength to 50 per cent. of its value at normal temperature.

(iii) *Life of Aircraft Structures.*—An investigation of great importance to civil aviation is the estimation of the number of flying hours an aircraft may be operated with reasonable safety. Past experience is of little value as an index of future trends because a number of design factors are combining to increase liability to failure by fatigue. Thus, working stresses and cruising speeds have increased while the increase in size of aircraft has reduced the resonant frequency of the wing structure to something approaching the gust frequency so that continuous oscillations of the wing can be expected. A solution of the problem involves investigations in a number of related fields, and the Division is making flight, laboratory, mathematical, and fundamental material studies which are co-ordinated and directed to the main purpose.

(*a*) *Flight loads.*—The nature and magnitude of the fluctuating loads to which aircraft are subjected in normal flights over civil air routes are of immediate importance, but the experimental data available are very meagre. In consequence, more vigorous operational research has been recommended by the British Commonwealth Conference; in Australia a Flight and Ground Loads Panel has been set up by the Council to co-ordinate its efforts with those of the Royal Australian Air Force, the Department of Civil Aviation, the air transport operators and the Meteorological Bureau.

Velocity load (V–G) recorders have been fitted to civil aircraft flying on regular scheduled routes and to a Royal Australian Air Force Dakota on the Australia-Japan run. Two series of flights were made in a Lincoln in the Darwin area to obtain data on tropical flying in both summer and winter conditions. Analysis of the records showed general similarity of loads of various magnitudes to those obtained in England, but the frequency of occurrence of loads of all magnitudes was appreciably higher. Comparative results at high speed were also obtained on a Meteor, but the results can only be regarded as of a preliminary nature. Not nearly enough data have been obtained as yet for adequate statistical analysis, and the work is being continued actively.

The analysis of graphical records is a tedious process requiring a good deal of manpower; to obviate this difficulty, a stress level counter which counts the number of times a given stress is reached in the main spar of the wing during a flight has been constructed. This information can be used directly in life prediction, and simplifies the work enormously. A prototype has been constructed, having six steps which are adjustable in value. Proving tests have been made, and the instrument will be placed in operation. Recording accelerometers which use electric resistance strain gauges as the recording elements have also been developed for investigating the distribution of accelerations in various parts of the structure.

(*b*) *Dynamics of structures.*—When an aeroplane encounters a vertical current of air, or gust, the load on the wings alters rapidly. This is equivalent to applying a sudden load, and as the wing is elastic it deforms and may vibrate in dissipating the effect of the gust. In addition to the measurement of these vibrations by flight experiments, a mathematical attack has been made on the problem. It is confidently expected that this attack, aided by the experimental data, will yield considerably more information than could be obtained by a long and costly experiment. The results achieved to date enable the magnitudes and the fluctuations in the accelerations and stresses at selected points on the structure to be determined during a finite period of time, from the measured or assumed variations in the gust forces. The theory includes flexural and torsional deformations of the wings due to either symmetrical or unsymmetrical gusts and is being extended to the more complex motions of the aircraft which are possible in flight.

(*c*) *Repeated load tests on aircraft structures.*—The effect of fluctuating loads on the endurance of an aircraft structure is almost impossible to predict in the present state of knowledge, and because of the large size of aircraft structures and of the high loads involved experimental work in this important field has proved very difficult. However, by a simple modification to its hydraulic testing equipment, the Division has been able to subject a number of Mosquito aircraft wings each to several thousands of repetitions of loads which fluctuated between 25 and 90 per cent. of the failing load of the structure.

The general conclusion arrived at from this work was that the static strength of wooden wings was not appreciably affected by up to 5,000 repetitions of loads fluctuating between 25 and 90 per cent. of the ultimate load. A similar series of experiments is in hand on metal wings. It is also intended to investigate the effect of a much greater number of repetitions of smaller loads which are more damaging from the fatigue point of view, and a technique utilizing the resonance characteristics of the wing has been evolved for this purpose.

3. *Engineering Materials.*—(i) *Fatigue of Metals.*—Ever since Wöhler first recognized the phenomenon of "fatigue" and performed his original experiments about 1860 in an endeavour to throw some light on this peculiar property of materials, much energy has been expended in the study of the subject. Despite this considerable effort, very little real progress has been made in the understanding of the fundamentals of fatigue or in the application of fatigue data to design problems.

The fatigue of metals is now becoming such an important topic in engineering design that it was deemed desirable to hold a symposium on the subject to disseminate existing knowledge and to encourage further thought and investigation. This symposium was convened and organized by the Faculty of Engineering of the University of Melbourne aided by a small committee, and strong support was given by a number of other organizations including the Council. Some 30 original papers were presented—10 from overseas authorities and 20 from Australia of which 6 were contributed by the Division.

A study of the problem of estimating the endurance "life" of an aircraft structure or component when acted on by the fluctuating loads encountered in flight has revealed a large number of gaps in the basic knowledge which the more academic studies have failed to bridge and which have rendered such studies of little practical value. However, it has been possible on purely theoretical grounds to generalize some of the more important notions on fatigue and to devise tentative methods for estimating the endurance of structural components and mechanical details. For example, a method of deriving S-N curves for any load range ratio given only the simple Wöhler curve has been devised, and suitable analytical functions for expressing strength reduction factors in terms of the geometrical stress concentration factor and the stress concentration variable have been evolved.

These and other significant speculations need experimental confirmation, and a programme of suitable experiments is under discussion by the Engineering Group Committee which will review the progress of work done in a number of co-operating laboratories. An important factor frequently overlooked in fatigue experiments is the method of preparing the specimens for test. The usual machining processes, such as turning or grinding, deform the material at and near the machined surface to such a degree that its fatigue characteristics are appreciably altered; subsequent surface polishing by buffing or similar operations only increases the deformation by smearing the surface. For fatigue specimens it is essential to develop a finishing technique which will ensure that the surface and sub-surface regions are disturbed as little as possible. An investigation of this problem which is still in progress has revealed a number of interesting facts. For example, it is practically impossible, by purely mechanical means, to produce a surface which is reasonably free from distortion. With metallurgical polishing, in which the surface is wet polished by hand, using a very fine abrasive of closely controlled particle size, distortion occurs to a depth of about 5 microns (about 200 millionths of an inch). The actual surface to a depth of one or two microns appears to be somewhat softer, as indicated by the micro-hardness tester, than the regions immediately underneath it, which themselves, owing to cold working, are appreciably harder than the basic material of the specimen. These effects are being investigated further. The actual surface roughness, as measured by the technique known as taper sectioning, is considerably greater than that indicated by standard surface measuring instruments which give a magnified trace of the motion of a stylus drawn over the surface and which therefore are not sufficiently sensitive for this particular investigation.

(ii) *Internal Damping Capacity.*—The internal damping of a structure is of importance when vibrations near the resonant frequency occur. Practically

no data on the values of the internal damping of structures made of several parts connected together are available. No systematic work has yet been commenced at the Division, but an interesting investigation of the damping capacity of cold stretched steel was made as the result of discrepancies noted in testing specimens in an electro-magnetic fatigue machine. In order to straighten some of the specimens which could not be vibrated satisfactorily they were cold stretched. The damping characteristics of the stretched and unstretched specimens were noticeably different, and an investigation of the relation between damping capacity and cold working was made. Besides throwing some further light on the mechanism of the deformation of bars under load and on the effect of plastic deformation on damping capacity, this investigation also contributed to the knowledge on strain aging as it was found that the damping capacity of certain of the specimens changed appreciably over a period of months.

(iii) *Properties of Alloys.*—During the war a great deal of work was done on the aluminium alloys and steels used for aircraft production. In both these types of alloys some work was done on the phenomenon of the change in properties with time, known as age hardening, which is vital to the engineering use of aluminium alloys and is also of interest in the case of low carbon steels, where it is called strain aging. It is believed that hardening occurs by the precipitation of a second phase from a supersaturated solid solution, the precipitation being helped in some cases by the effect of plastic strain. More recently, investigations which have commenced on high temperature materials have indicated that age hardening may be of great benefit in resisting creep at high temperatures. It is clear that more fundamental knowledge of this aspect of the theory of alloying would give an insight into a phenomenon which has such widely differing results of practical importance. An attack on the problem will be commenced with an investigation of the strain aging of steels. As a preliminary, the preparation of pure iron is being undertaken, and the structure of mild steel subjected to a uniform strain and then given different thermal treatments which confer differing degrees of strain aging, is being examined with the aid of an electron microscope. A study of the stored energy in cold-worked metals will, it is hoped, contribute something to our understanding; this phase is being undertaken in collaboration with the Metal Physics Group of the Tribophysics Section. The energy is to be determined from specific heat measurements of both annealed and cold-worked metals.

(iv) *High Temperature Alloys.*—(*a*) *Alloy systems.*—The future of gas turbines is assured from some aircraft and industrial applications, but the field of use would be considerably widened if higher thermal efficiencies could be obtained. One of the limiting factors at present is the permissible temperature of the materials used in certain parts, e.g., the turbine nozzles and blading, and so far progress has been mainly due to commercial firms which have modified existing high temperature materials, such as stainless steel. It was clear, however, that any substantial further progress could only be achieved by a more fundamental approach to the general problem of heat resistance in metals; this approach has been made, using modern knowledge of the physics of metals and the theory of alloying. It has been centred mainly on the characteristics of inter-atomic cohesion and strength of the grain boundaries, and has resulted in the selection of several alloy systems as being worthy of further study. The binary systems chromium-tungsten and chromium-beryllium will be investigated in the first instance. Alloys of chromium-tungsten ranging from 0 to 100 per cent. in 10 per cent. steps have been prepared from vacuum-treated electrolytic chromium and hydrogen-reduced tungsten by sintering *in vacuo* in an induction heating furnace. These alloys were found to consist of a single solid solution at room temperature; further measurements are being made to determine the complete binary phase diagram. The chromium-beryllium alloys will be produced by high frequency induction melting in a vacuum furnace, but production has not yet commenced.

(*b*) *Grain boundaries.*—The mode of failure of materials at high temperature is very different from that at room temperatures when failures under tensile load, for example, ultimately occur by cohesive failure of the crystals themselves. With increasing temperatures the grain boundaries apparently become weakened until a temperature is reached above which a failur occurs not by fracture through the crystals or grains but by separation of one from another at their boundaries. An attempt to elucidate this important aspect of the metallic state has been commenced by studying specimens of lead and tin consisting of two crystals having a common plane boundary parallel to the longitudinal axis. These crystals are grown by slow solidification from two seed srystals which give the desired orientation to the bicrystals. Care has to be taken that oxide impurities are excluded from the grain boundary.

Special high temperature creep testing machines have been obtained for evaluating new alloys which, it is hoped, will be forthcoming from these fundamental studies.

(v) *Powder Metallurgy.*—During the war the Division undertook investigations in connexion with the production of porous bronze bearings for aircraft use. Later, a thorough study of the variables affecting the sintering process was made, and it became clear that the process had two important aspects: diffusion of one metal into another and solid phase bonding of either like or unlike metals. The same two phenomena had been encountered in the extensive work which had also been done on copper brazing and pressure welding of steel.

While powder metallurgy is a technique of wide application, it is of particular use with high melting point metals where alloying by melting is practically impossible. Hence the studies of the fundamentals of powder metallurgy have been continued in connexion with the high temperature materials programme. Apparatus has been constructed for the measurement of hardness, density, electric resistivity, and linear dimensions, the two latter at high temperatures, and various methods of determining particle size distribution have been tried. On the practical side alloys containing tungsten have been successfully sintered.

(vi) *Corrosion.*—A report covering the investigation into corrosion in aircraft coolant systems has been published. The experimental work in this field is being continued with the measurement of electrode potentials and currents between the various components of an aircraft engine cooling system during controlled running on a test bed. As part of the tests, air in the header tank was replaced by nitrogen in order to determine the amount of oxygen required to cause corrosion by differential aeration.

The work on corrosion of condenser tubes in power stations has also been continued. The electrochemical characteristics of aluminium bronze and other alloys used in the manufacture of such tubes were evaluated and the principles of the corrosion of tubes in salt water were determined. A practical result of the investigation was that aluminium bronze was shown to be superior in corrosion resistance to Admiralty brass. Work on the nature of the protective films formed is now proceeding.

The discussions at the Fatigue Symposium showed that the fundamentals of stress and fretting corrosion and corrosion fatigue were little understood. A steady stress machine has therefore been constructed to

measure the effect of stress on the electrode potential of various metals and alloys; a commencement has been made with the examination of films on aluminium wire. Later similar measurements of specimens under fatigue stresses may be made.

4. *Aerodynamics.*—The Commonwealth Conference drew attention to the need for aerodynamic research in certain fields, particularly in the realm of very high speed flight. The Division is working on some aspects of the relevant problems.

(i) *High Speed Subsonic and Transonic Flow.*—In the past ten years, speeds obtained in flight have increased from about 400 to just over 600 m.p.h. This increase has been achieved by some refinement in aerodynamic design but mostly by replacing the conventional engine and airscrew by jet propulsion. In the next ten years much more powerful jet engines will be built, but the achievement of another 200 m.p.h. increase in speed in that time will depend less on the power of the engines available than on the solution of the aerodynamic problems involved. The speed of sound is about 750 m.p.h., and as this speed is approached and passed the whole nature of the airflow changes. It is probable that, when the speed of sound is greatly exceeded and full supersonic flow is established, the problems of aerodynamic design will not be very difficult, but in the transition region between sub and supersonic flow, very little knowledge is available, though there are indications that a very large increase in resistance, coupled with violent changes of control and stability, occur.

A group has been formed to investigate some of the general problems of high speed subsonic and transonic flow. Any knowledge gained will be useful not only in the design of high speed aircraft but in the design of jet engines to propel them. Unless these are of the rocket type, air must be taken in and its supersonic velocity converted to pressure at a lower speed. To do this efficiently is a major problem.

So far, the main preoccupation of the group has been the completion of the variable pressure tunnel—the major item of research equipment. The tunnel itself, with its electrical drive, compressing, exhausting, and cooling systems, is complete. A very low value of the turbulence in the working section is required and has been achieved by an arrangement of fine wire gauze screens, placed in the largest section of the tunnel just ahead of the contracting nozzle. Extensive experiments were made to find the optimum arrangement. Certain items of subsidiary gear are incomplete and until they are available research in the tunnel itself cannot go forward. One item is the air drier, since moisture condensing in the working section after the sudden decrease in pressure would introduce instability into the shock wave pattern. Means are also required for rendering the flow visible, since the normal methods of exploration, such as the introduction of pressure-measuring tubes, would themselves create shock waves. Preliminary experiments on a new type of interferometer show promise, and it is planned that when the pilot model has been proved large-scale apparatus will be constructed.

While most of the effort has been expended in the preparation of the equipment, research has not been neglected. An officer was sent abroad to study the mathematical methods applicable to compressible flow; his knowledge has been imparted by a series of lectures and seminars. The nature and mode of formation of shock waves is a fundamental objective, and an attractive, though not really simple, method of study is the creation of shock waves in a uniform tube by the accelerated motion of a piston. A mathematical analysis has been made of the formation of a shock wave when the piston accelerates uniformly, and a shock tube is being built to verify the theoretical results. Difficult mechanical problems are involved as, in order to make the best use of optical methods for examining the flow and studying the formation of the shock wave, the tube must be of rectangular cross section. Moreover, the piston will travel at speeds approximating to the velocity of sound.

(ii) *The Use of Suction to Increase Efficiency at Moderate Speeds.*—The great majority of aircraft, and particularly large aircraft, will continue to operate at medium speeds, and in the field of civil aviation it is important that aircraft operating at speeds of 400 m.p.h. and under should do so as efficiently as possible. There are two aerodynamic requirements for efficiency. Firstly, the drag or resistance of the aeroplane to its passage through the air must be reduced. This allows a higher speed with a given power and a greater range with a given fuel load. Secondly, the maximum useful volume for a given resistance increases the economy of carrying passengers and bulky freight.

Aeroplanes have become progressively cleaner, until streamlining has reached such perfection that the drag of the modern airliner is largely due to surface friction. A further reduction in drag can only occur in one of two ways: by reducing the surface area, e.g., by eliminating the fuselage and turning to an all-wing design, or by reducing the intensity of friction per unit of area. Recently, Dr. A. A. Griffith in England has suggested a most original way of using suction to achieve both objectives. The smallest values of skin friction are obtained when the flow near the surface is laminar, and the Griffith wing achieves laminar flow over the whole surface by introducing a discontinuity at which a suction slot draws off the boundary layer. The resulting shape is very different from a normal aeroplane wing profile. The idea makes possible very thick wings which will have drags not appreciably greater than the thin wings now customary. This makes the flying wing type of aeroplane practicable for passenger-carrying in comparatively small sizes; heretofore it has been estimated that to give the necessary headroom the smallest all-wing aircraft would weigh about 100 tons.

At the National Physical Laboratory in England extensive theoretical and wind tunnel studies have been made, but the idea has not yet been applied to a practical design. At the request of the Commonwealth Conference the Division has undertaken to make flight experiments. To start with, the simplest possible aeroplane has been envisaged. This consists of a towed glider so that the complications of an engine and propeller are avoided. The glider will be fitted with a 30 per cent. thick suction wing, the boundary layer being removed by a motor-driven blower carried in the fuselage. A great many problems have been thrown up even by this comparatively simple experiment, e.g., owing to weight and space limitations, the blower could not be duplicated and the safety aspect in case of failure of the suction had to be covered. Thus, the first experiments made in the wind tunnel were to determine the characteristics of the wing without suction. Another unexpected difficulty was that modification of the theoretical shape of the wing in the neighbourhood of the slot had to be determined before the power absorbed in suction could be reduced to an acceptable figure; this is being done by wind tunnel work on full-sized wing sections. Willing co-operation in this research has been obtained from the Royal Australian Air Force, which supplied the glider and will undertake the flight experiments, and the Aircraft Production Division of the Department of Munitions which is constructing the special wing.

(iii) *Turbulence.* — The immediate programme planned is research into the nature of turbulence behind wire screens, as the use of such screens in wind tunnels for reducing turbulence is almost universal. Preliminary work is in hand. A review of the available information has been made and has revealed inconsistencies which will be investigated. The longitudinal and

lateral components of turbulence are being determined in the wake of a cylindrical rod; methods of analysing the data which will be obtained in measurements of scale, spectrum, and probability distribution of the components of turbulence are being devised.

The 2-ft diameter turbulence tunnel in which the main investigations are made has been unsatisfactory because of velocity fluctuations. Owing to space limitations, the tunnel was made with a right-angled bend and was placed unsymmetrically in the containing room. Recently, more space has become available, and it is now possible to eliminate the bend and place the tunnel symmetrically. At the same time the centrifugal fan is being replaced by a six-stage axial flow fan, which is better fitted to cope with the varying resistance of the tunnel caused by the introduction of gauze screens.

At the University of Sydney an experimental investigation of turbulent boundary layers and the factors leading to separation is in progress. In particular, the effects of external periodic disturbances and turbulence on separation are being studied.

(iv) *Development of Radio-controlled Flying Models.*—High-speed flight experiments in the present state of knowledge are too dangerous to undertake with piloted aircraft. Moreover, a wind tunnel, unless of prodigious size and power, is not a reliable guide to the behaviour of a complete machine. Thus a need for free flight models, which can be controlled by radio, emerges. There are, however, other uses for such models; for example, the Division of Radiophysics has a need for small radio-controlled aircraft carrying meteorological instruments which can be flown under dangerous weather conditions, e.g., in the interior of cumulus clouds, in rain-making investigation. Further, the Division has envisaged the use of flying models for researches in stability and aero-elasticity, and a start has been made to develop this useful technique. A small all-wing glider which by wind tunnel and flight tests overcame the initial difficulties associated with the stability of the unorthodox design was first developed by the Sydney University Research Group. The aerodynamic form was then reproduced in the Division as a larger model, powered with a small petrol engine and launched by a rocket-driven catapult. This model of 5-ft. span having proved successful, the construction of a 12-ft span power-driven model is now well advanced. This will be large enough to carry radio control gear developed by the Division of Radiophysics.

(v) *Industrial Aerodynamics.*—In the past, very considerable assistance has been given to industry, mainly in the direction of testing by means of wind tunnel models the characteristics of new types of aircraft. A small volume of this work is still undertaken, two or three alternative designs of a small training aeroplane having been submitted by the Aircraft Production Division.

Another direction in which industry is continuously requiring assistance is in the design of axial flow fans and blowers. The theory of the design and analysis of such fans was developed in connexion with wind tunnels, but since then the knowledge has been used for many industrial applications. Two of particular interest were developed during the year. The first was undertaken at the request of a fruit-growers' association which required an improved orchard sprayer. A prototype was constructed in which the spraying fluid is injected into a high-speed air blast which carries the droplets to a height of 20 feet and distributes them in a cloud over a considerable area. The coverage obtained with this form of airborne spray is very good; great interest has been shown by growers' associations in Australia and the prototype has been lent to the New Zealand Government.

The other application was for frost control. Large low-speed fans have been built which are mounted on towers, the fan rotating in a horizontal plane. During still frosty conditions a temperature inversion occurs and an immense reservoir of warm air lies above the cold air which covers the ground. The frost fan draws down this warm air which spreads outwards around the fan along the ground, displacing the cold air and protecting trees and fruit from damage. Preliminary tests give promise that 3 acres can be protected with each 10 h.p. fan installed, but more extensive field tests which are now under way will be needed to prove this indication.

5. *Aircraft Propulsion.*—The main effort in this field is now devoted to turbine engines for either jet propulsion or driving propellers. Unfortunately, little of the existing reciprocating engine equipment is suitable in its present form for turbine investigations and, consequently, a great deal of time has been spent in designing and modifying apparatus.

(i) *Combustion.*—Aircraft gas turbine combustion chambers operate with higher rates of heat release per unit volume than any other combustion device; at the same time high thermal efficiency and low pressure drop must be maintained over a wide range of operating conditions. Reasonably satisfactory chambers have been designed using *ad hoc* methods, but little is known about the fundamentals of their operation. Research is being undertaken to throw light on the basic principles of operation of high intensity combustors; it is clear that further improvements in design can only result from a clear understanding of these principles.

Combustion research in the present state of knowledge cannot be carried out with small models, and to do work on an adequate scale a large supply of air is needed at pressures equal to those used in turbines. Tenders have been called for a 2,000 horse-power air compressor, having a compression ratio of 10 : 1. This plant will have a useful, but by no means excessive, capacity for combustion investigations; it will also be possible to use it for operating a supersonic tunnel.

Unfortunately, under present conditions it will be more than two years before such a plant will be delivered. Meanwhile combustion research at atmospheric pressure is to be done, utilizing available low pressure fans. As a preliminary, a report has been prepared summarizing the present state of knowledge in regard to factors affecting combustion. Resulting from this survey, the first research will be to determine the effects of turbulence. A combustion chamber employing the same principles as are used in current turbine practice has been designed so that the air admitted to the various zones can be separately controlled. The turbulence-producing devices will be altered and the effects on the chemical process, flame characteristics, pressure loss and temperature distribution studied.

At least two new techniques must be developed. Firstly, turbulence-measuring apparatus which will operate at much higher speeds and measure much greater velocity fluctuations than the apparatus normally used in aerodynamic research is required; secondly, the measurement of gas and flame temperatures up to 2,000° C. introduces a number of new problems.

(ii) *Thermodynamic Cycles and Turbine Performance.*—Improvements in gas turbines will undoubtedly entail complication in the form of compound turbines with heat exchangers, intercoolers, and other devices for improving efficiency. On the advice of the Commonwealth Council, theoretical analysis of the efficiency, control, and stability of various thermodynamic cycles has been concentrated in England, and an officer of the Division has been seconded to the National Gas Turbine Establishment for this work.

The 2,000 h.p. engine test plant is being redesigned to accommodate jet and turbine-propeller engines. In order to study certain design features of the new plant, a temporary jet engine test stand was constructed and has been in operation during the year. Rolls-Royce, Welland and Derwent engines have been run, and some tests have been carried out for the Royal Australian Air Force.

(iii) *Compressor and Turbine Blading.*—(*a*) *Aerodynamic design.*—Axial flow fan theory developed in the Division postulates that the blades are sufficiently far apart to be considered as independent elements. In compressors, in order to achieve a large pressure rise per stage, closely-spaced blades of high camber are needed. The axial flow fan theory breaks down because of mutual interference between adjacent blades, and the characteristics of blades "in cascade" must be determined in a special form of tunnel. Theory is available to design aerofoils in cascade to give any desired pressure distribution, and a low speed cascade tunnel is being constructed to determine experimentally the distribution for minimum losses and the effect of Reynolds number on these losses. Later, it is hoped to extend the work to the high Mach numbers met in practice.

In cascades used in turbines, the flow is accelerating, and the problem of efficient aerodynamic design is not nearly as difficult as for compressors. Little work is therefore contemplated in this field at the moment. A review of the elementary theory of centrifugal compressors, axial flow compressors, and turbines has been written.

(*b*) *Construction.*—The aerodynamic requirements for high efficiency lead to shapes which are difficult to produce. A summary of existing blade machining practice has been written; it describes the special forms of machine tools which have been evolved.

Even with appropriate machines, production is slow and the wastage of costly material high. Casting or pressing the blades accurately to form is therefore attractive, and the "lost wax" process which for centuries has been used for casting statues has been applied to this problem. The application of the technique to materials which melt at very high temperatures needs moulds of an extremely refractory nature. Experimental moulding equipment has been made and work is proceeding on alumina base investments which, it is hoped, will withstand the temperatures needed for the chromium-beryllium alloys which are being developed.

(*c*) *Vibration characteristics.*—Fatigue of turbine blading resulting from resonant vibration is a common cause of failure. Calculation of the natural frequencies of blades must take into account the complicated shape and the effects of centrifugal force. No general solution of the mathematical problem of calculating the resonant frequencies has yet been found, and it is customary to rely on practical tests. At the suggestion of the Commonwealth Council, a mathematical analysis is being made to find whether a simplified and workable method of computing natural frequencies can be devised.

6. *Mechanical Engineering.* — (i) *Piston Ring Lubrication.*—The conditions of lubrication between piston rings and the cylinder wall, which determine the rate of wear of the parts, have been examined by measuring the electrical conductivity of the oil film, a technique developed by the Tribophysics Section. The tests were made with a full-sized aero engine cylinder under normal running conditions and the first series of tests covered the effects of engine speed, power, cylinder temperature, spark advance, and detonation.

It was demonstrated that the factors which adversely affected lubrication were: low engine speed, especially during starting, high cylinder pressures (full throttle), high cylinder temperature, excessive spark advance, and low oil circulation. It was found that in general the rubbing surfaces were separated by a complete oil film only near the centre of the stroke and the presence of detonation caused prolonged breakdown of the oil film. These tests have been reported and a second series commenced in which the influence of various lubricating oils and differing shapes of piston ring cross-section will be determined. Tests have been completed using oils of various origins and different viscosities and are being continued to find the effect of additives such as detergents, anti-oxidants, and so-called "oiliness additives".

(ii) *Rotary Valve Engine.* — Development of the rotary valve engine has continued. The 500 cc. single cylinder engine has been modified for high speed operation; with a large port area and a wide valve overlap, 20 h.p. has been obtained at 4,000 r.p.m. and speeds up to 5,500 r.p.m. reached. It is expected that performance will be further improved when a larger carburettor is fitted.

The knowledge gained has been used to design a twin cylinder rotary valve engine intended as an auxiliary power plant for aircraft and a prototype is being constructed by the Aircraft Production Division for the Royal Australian Air Force. A commercial firm has also utilized the rotary valve in a single cylinder stationary Diesel engine for industrial use.

(iii) *Engines for Flying Models.*—For propulsion of the larger radio-controlled flying model aircraft, to which reference has already been made, two types of power plant have been under consideration. A miniature pulse-jet engine, fundamentally similar to the engine of the German flying bomb, has been tested and its performance analysed; it is likely that the high fuel consumption and mechanical unreliability of engines of this type will militate against their success. As an alternative, a small two-cylinder two-stroke reciprocating engine has been designed and is under construction; it is expected to develop at least 3 h.p. and its weight will be about 7 lb.

(iv) *Automotive Investigations.* — The design of cooling systems of automobiles and trucks appears to be capable of improvement. Tests which have been made to improve particular installations show that the cooling fans work under such unfavorable conditions that an appreciable proportion of the engine power is absorbed in driving the fan. In the light of aerodynamic knowledge, fan and duct systems of high efficiency are easy to suggest; the difficulty lies in introducing the modifications into production designs.

The heat dissipation, cooling air flow, and hydraulic resistance of a series of automobile type radiators have been measured, the radiators differing in core material and dimensions. An analysis of the heat transfer coefficients is proceeding, and it is hoped to correlate this work with that carried out previously at the Sydney University Engineering Laboratories.

Two versions of a tractor were tested according to the Nebraska code. Following the tests, further work which markedly improved cooling under high temperature conditions was done and lubrication under certain adverse working conditions was investigated. Local manufacturers value the opportunity to have their tractors tested according to a standard which has now become an international yardstick.

(v) *Plant for Suction Wing Research.*—In the ultimate development, suction for boundary layer control will be provided either by the turbines used

for propulsion of the aircraft or by blowers driven by the turbines. For the towed glider experiment already described, special plant had to be developed to meet the stringent limitations of size and weight coupled with a very high pressure difference.

A single-stage centrifugal blower was finally chosen, and designed to be driven by an automobile engine modified for flight operation. The high-efficiency blower is of similar type to those used for supercharging aero engines, but complicated machining was avoided by fabricating the components in welded steel and aluminium alloy. This plant is undergoing tests prior to installation in the glider.

(vi) *Dust Investigations.*—During the war excessive engine wear due to dust in the air entering aircraft engine cylinders was common; in extreme cases the cylinders and piston rings were worn out in a few hours' operation. The development and improvement of specific types of air cleaners was undertaken, special techniques being evolved, but this work was tapered off during the year and the effort transferred to the more general study of the factors affecting the design of air cleaners. An investigation is now in progress to determine the effect of the geometry of the filtering material on the pressure drop, which is one of the important characteristics determining the acceptability of a cleaning system.

The filtering efficiency and pressure drop of a given design of cleaner vary with the amount of dust trapped, and it is therefore important to be able to estimate the amount of dust the engine is likely to aspirate under operational conditions. Apparatus has been installed in a Royal Australian Air Force Beaufighter and dust concentration determined in flight. Measurements were made in clear and hazy weather and also in a moderate dust storm. Results show that the highest concentration, even in clear weather, exists at about 1,000 feet and that particle size decreases with increasing height. It was also shown that severe dust concentrations can persist up to considerable heights during a dust storm.

7. *Electronics and Instruments.*—The research and experimental investigations which have been described would have been hampered, and in some cases quite impossible, without the appropriate instrumental aids. While standard and commercially available apparatus is often suitable, in a great many instances special apparatus, together with the corresponding technique of measurement, must be developed. Electronics is probably the most versatile vehicle, but other branches of physics have played their part in enabling the requisite scientific measurements to be made. The instrumental aids have been so many and so diverse in character that only a few of the more interesting can be recorded.

Electric resistance wire strain gauges continue to be a most convenient method of measuring and recording forces. They are used very frequently in static load measurements in the laboratory and a new form of bridge was devised. The indicating mechanism is such that the bridge need be only roughly balanced, as a moving zero makes the correct allowance for the residual unbalance. The ease and speed of taking readings is thus greatly increased. Electric strain gauges form the measuring devices in a three-component balance small enough to be housed inside a wind tunnel model and have also been used for measuring the static and dynamic loads in a compression-tension fatigue machine. As part of the flight load investigation, strain gauges are attached to important parts of the aircraft structure. To record the rapid variations in load during flight a fifteen-channel oscillograph has been procured from America.

A strain counter has been developed and tested in connexion with work being carried out on the life of aircraft structures. A mechanical extensometer is used on which are mounted microswitches, and these are set to operate at various strain levels. The switches are connected in a thyratron circuit which operates a Postmaster-General counter. Thus the number of times the strain exceeds the various strain levels is counted, but the circuit is so interconnected that, after a strain level has counted, it cannot count again until the strain passes through the zero level.

Relaxation methods are a powerful mathematical tool which would be more widely used if the associated computation was not so laborious. A machine for solving the basic equations has been devised and a prototype, of which there would be a number of similar units in the complete machine, is being constructed for test.

Work for outside bodies has also been done. Thus, alternating current would have certain advantages over direct current for the electric supply system of aircraft, but the difficulty exists of obtaining constant frequency from the engine-driven alternators whose speed of rotation is variable. So that the alternators can be run in parallel, a proposed method of obtaining constant frequency was submitted by the Royal Australian Air Force, but a theoretical investigation showed serious defects. However, modifications of the scheme to give a practical solution have been devised and a laboratory model of a variable-speed constant-frequency generator is being constructed for test.

A metal detector was designed to detect steel wedges which are occasionally left in logs and which would cause grave damage to paper pulping machinery. The aerodynamic measuring instruments for the new wind tunnel which is being put into commission at the Melbourne Technical College were made, and for other Divisions of the Council special instruments, e.g., temperature controllers, a supersonic vibrator, an interval timer, and several bolometers, were designed and built.

8. *Publications.*—The following papers were published during the year:—

Batchelor, G. K. (1946).—Theory of axisymmetric turbulence. *Proc. Roy. Soc.*, A. 186: 480.

—— (1946).—Recent deductions concerning the double velocity correlation function in turbulent motion. Proc. Sixth Int. Congr. Appl. Mechanics. (Also *Nature* 158: 883-4, 1946.)

Batchelor, G. K., and Townsend, A. A. (1946).—Vorticity changes in isotropic turbulence. Proc. Sixth Int. Congr. Appl. Mechanics.

Cowley, J. M., and Paterson, M. S. (1947).—X-ray diffraction studies of yielding in mild steel. *Nature* 159: 846.

Cumming, Betty L. (1946).—Review of turbulence theories. Aust. Coun. Aero. Rept. ACA-27.

Dailey, G. J., and Dale, F. A. (1946).—Temperature measurements on a Beaufort during summer at Alice Springs and at Melbourne. Aust. Coun. Aero. Rept. ACA-26.

Edwards, A. R. (1946).—Fatigue problems in the gas turbine aero engine. Paper 22 contributed to the Symposium on the Fatigue of Metals, Univ. Melbourne.

Freiberger, W., Shaw, F. S., Silberstein, J. P. O., and Smith, R. C. T. (1947).—Plywood panels in end compression. Flat panels with grain at various angles to direction of loading. Aust. Coun. Aero. Rept. ACA-30.

Hooton, F. W. (1946).—The measurement of dynamic strain. Paper 10 contributed to the Symposium on the Fatigue of Metals, Univ. Melbourne.

Johnstone, W. W. (1946).—A review of current methods for strength testing of aircraft wings. Aust. Coun. Aero. Rept. ACA-28.

—— (1946). — Methods of investigating the fatigue properties of materials. Paper 11 contributed to the Symposium on the Fatigue of Metals, Univ. Melbourne.

Mann, Elizabeth H. (1946).—Theory of the Bourdon tube. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 122-35.

Osborn, C. J. (1946).—The fatigue of welded steel tubing in aircraft structures. Paper 18 contributed to the Symposium on the Fatigue of Metals, Univ. Melbourne.

Paterson, M. S. (1946).—Notch sensitivity of metals. Paper 19 contributed to the Symposium on the Fatigue of Metals, Univ. Melbourne.

Scholes, J. F. M. (1947).—Ducted fans—A nomogram method of analysis. Aust. Coun. Aero. Rept. ACA-32.

Shaw, F. S. (1946). — Determination of stress concentration factors. Paper 12 contributed to the Symposium on the Fatigue of Metals, Univ. Melbourne.

Silberstein, J. P. O. (1947).—Plywood panels in end compression. Curved panels with grain at various angles to generators. Aust. Coun. Aero. Rept. ACA-31.

Smith, R. C. T. (1946).—The buckling of plywood plates in shear. Aust. Coun. Aero. Rept. ACA-29.

Smith, R. C. T. (1947).—The approximate solution of equations in infinitely many unknowns. *Quart. J. Math.* 18(69): 25.

Thompson, P. F. (1946).—Corrosion of metals: Metals in aircraft engine cooling systems. Aust, Coun. Aero. Pept. ACA-24.

——(1947).—Dissolution of gold in cyanide solutions. Electrochemical Society Preprint 91-26, presented at 91st General Meeting, Louisville, U.S.A., 9th April, 1947.

Wain. H. L. (1946).—Powder metallurgy: Influence of some processing variables on the properties of sintered bronze. Aust. Coun. Aero. Rept. ACA-25.

XV. INDUSTRIAL CHEMISTRY.

1. *General.*—The Division's small Dairy Products Section has been amalgamated with the existing Dairy Research Section of the Council, and, following the resignation of Dr. W. J. Wiley, its leader has been appointed Officer-in-Charge of the combined Section. This is an independent Section but is temporarily accommodated within the Division's buildings. With this change, and the winding up of the Section of Physical Metallurgy during the previous year, the Division has practically concluded war-time activities lying outside its true scope.

Several Sections of the Division are attempting to revise their programmes so that they will be of greater value to the community. It seemed a fitting time, therefore, to send a number of officers abroad with a view to obtaining additional training and to becoming more familiar with the research work being conducted in Great Britain, Europe, and America. Twelve officers have been overseas during the year, of whom four hold Senior Studentships granted by the Council.

Progress has been made with the inauguration of ceramic research. In collaboration with the Geology Department of the University of Melbourne and with the Department of Mines in South Australia, a survey of raw materials of value to the ceramic industry has been commenced, and is being vigorously prosecuted. This will be extended to other States in due course. An officer has been appointed to lead the more fundamental investigations to be undertaken at Fisherman's Bend. An agreement has also been reached to co-operate with the South Australian State Mines Department and the School of Mines in setting up a ceramic laboratory in Adelaide, in which work of an essentially practical nature will be done.

Accommodation has been a pressing problem. The Biochemistry Section, having to vacate laboratories kindly made available during the war by the Division of Animal Health and Production, has been transferred to a temporary laboratory in the city. A new building has been designed, and its construction is expected to commence early in the next financial year. It will accommodate the Biochemistry and the Organic Chemistry Sections, and provide some space to relieve over-crowding in all Sections. In addition, several Army "huts" have been acquired to afford temporary relief from the congestion.

Every effort has been made to bring the results of the research work of the Division before the notice of those who are in a position to utilize them. Processes developed in the Division have been demonstrated to representatives of the industries concerned, and addresses have been given in many parts of Australia before appropriate trade associations.

2. *Minerals Utilization Section.*—An extension of the investigations outlined in the previous annual report has, for the most part, characterized the Section's activities, and the importance of some Australian mineral resources of certain of the lesser-known elements have again been stressed. The diversity of industrial intermediates often obtainable from any one mineral by appropriate chemical treatment is sometimes insufficiently appreciated. This fact, among others, has dictated a continuity of the research programme aimed at securing a maximum of fundamental and applied data for such minerals as are either well represented in Australia or which merit local attention for some other reason. The following headings indicate the progress made in the several fields. Reference should be made to the previous report for a more detailed statement of the scope of each project as a whole.

(i) *Chromite.*—The process devised for the production of chromic anhydride by acid digestion of chromite ore has been developed, in conjunction with the Chemical Engineering Section, as a cyclic operation. For this reason the satisfactory removal of the unwanted sulphates of iron, magnesium, and aluminium to avoid their excessive concentration in the circuit liquors is as essential as the more obvious requirement of removing the desired chromic anhydride. Laboratory studies on the relative solubilities of these by-product sulphates together with chromium sulphate in re-concentrated circuit liquors have therefore been undertaken. Equilibria in such viscous solutions are only slowly established, and this and other factors have required a cautious interpretation of the data when comparing laboratory and pilot plant conditions. The problem of removal of small amounts of sulphuric acid contaminant from the recrystallized chromic anhydride by treatment with soluble barium compounds has also been investigated.

(ii) *Monazite.*—In the current work on monazite, greater emphasis has been laid on the thorium content than on the associated rare earths. Combined pilot plant and laboratory studies have enabled a quantitative flow sheet to be drawn up, indicating the relative partition of the many constituents of the monazite at each stage of the processing. The distribution of the small uranium fraction has been included. Methods were evolved for the joint and individual hydrolytic

separation of cerium and thorium from the other components. The removal of small amounts of phosphoric acid from the derived thorium products has proved unexpectedly difficult and has received thorough study.

Anhydrous chlorination of monazite has also been investigated as an auxiliary process to the more usual acid digestion. By this means the phosphoric acid may be completely eliminated as volatile phosphorous oxychloride, while the rare earths and thorium remain as anhydrous chlorides. Preliminary work has shown a differential rate of chlorination for thorium. This may be of advantage in effecting at least partial separation of this component.

New methods for preparing simple and complex thorium fluorides were evolved and the properties of these compounds were investigated.

(iii) *Rutile.*—Pilot plant production of butyl titanate from titanium tetrachloride, derived from rutile, has continued with improvements and modifications made in conjunction with the Chemical Engineering Section. Considerable amounts of various titanium esters can now be produced. Investigations concerning the use of butyl titanate in paint formulations have been continued in collaboration with the Munitions Supply Laboratories, Maribyrnong. Tests of aluminium-butyl titanate heat-resistant paints have been made under various exacting conditions at several industrial plants and the results, to date, have been encouraging. Butyl titanate also appears to offer certain advantages when incorporated in normal paint formulae.

Studies on the formation of titanium nitride and the bonding of this extremely hard substance into shapes suitable for lathe tools, etc. have been continued with encouraging results.

(iv) *Zircon.*—For most of the year, work on the separation of zirconium and hafnium compounds from the mineral zircon was in abeyance but a considerable quantity of crude anhydrous zirconium tetrachloride was prepared for use in subsequent work. Certain anomalies encountered in the preliminary work have necessitated a recasting of this programme.

(v) *Uranium Ores.*—The cyclic process designed for the leaching of the low-grade phosphatic torbernite ores of the Mt. Painter field in South Australia, was not taken to pilot plant stage or installed under field conditions. Before doing so it was considered desirable to reinvestigate the problem with a view to achieving a maximum recovery of the available uranium rather than the optimum previously obtained under the limitations imposed by the field conditions. This new approach has made it necessary to view the problem from an entirely different angle. Preliminary work has been done on solvent extraction of various leach liquors. In this investigation it has been necessary to avoid inflexible processing specifications pending developmental work at the mines which may reveal variable grades, or types, of ore.

Preliminary work was also undertaken on a new method of treatment of the complex titaniferous uranium ore from Radium Hill, near Olary, South Australia, by a method based on fluoride processing instead of the alkali pyrosulphate treatment previously used.

(vi) *Graphite and Manganese Dioxide.*—The work on these two minerals has centred on their use in the electrical dry cell project and on the laboratory preparation of experimental dry cells. Particular attention has been directed towards obtaining reproducibility in performance, and determining the proportions and size distributions of graphite and manganese dioxide for maximum cell life. Several methods for the preparation of manganese dioxide have been shown to give very satisfactory products. South Australian graphite, if suitably purified and if ground fine enough, gives results at least equal to other natural and artificial graphites which have been examined. Investigations on the grinding and beneficiation of graphite have also continued, and products of quality suitable for lubricants have been prepared. Studies on the chemistry and physical properties of manganese dioxide relevant to the dry cell problem are still in progress.

(vii) *Fluorides.*—A thorough study of the factors involved in the preparation of aluminium fluoride by different methods was made. This involved the determination of fundamental data concerning the constitution of related compounds of aluminium and fluorine. Projects in which an accumulated experience of fluoride chemistry has been availed of during the current year include those dealing with aluminium, uranium, thorium, zirconium, hafnium, and graphite. Ammonium bifluoride, prepared directly from fluorspar, appears likely to be a very versatile reagent in effecting the decomposition of many refractory minerals.

3. *Cement and Ceramics Section.*—(i) *Cement Investigations.*—The problem of the deterioration of concrete through interaction of its cement and aggregate components has been the subject of further investigational work. The trend of this work suggests that when reactive aggregates are present, permanent immunity from expansion due to cement-aggregate reaction cannot be obtained even by the use of cements low in the alkali metals, sodium and potassium. Experimental work has shown that alkali metals migrate for significant distances through hardened mortar, that void-space is important with respect to expansion, and that tensile strength decreases as the reaction proceeds. These and other studies have shed much light on the fundamental mechanism of the reactions. Much information on the mineralogy of reactive aggregates has also been obtained, as the result of which it has been possible to advise certain public bodies on the choice of aggregates for projects of some magnitude.

These studies on cement-aggregate reaction have led to a broader study of the role of the alkali metals in portland cement. Initially an attempt is being made to determine the mode of occurrence of sodium in cement clinkers by means of phase-equilibria studies and petrological work on clinker containing controlled amounts of sodium. By these methods information is accumulating concerning the constitution of cement clinker and the effect of alkali metals on the setting time of cement.

Analytical methods, particularly those concerned with the determination of the alkali metals, have necessarily received attention. The use of flame-photometric methods is being developed.

The cement investigations have been assisted by the co-operation and financial support of the Cement and Concrete Association of Australia.

(ii) *Refractories Investigations.*—Work on refractories has been confined to two types of materials: (*a*) basic refractories for cement kiln linings, and (*b*) bricks for coal-gas retorts. Up to this early stage in these investigations it has been necessary to devote a good deal of time to the examination and development of laboratory methods. The National Gas Association is contributing both active co-operation and financial support to the work on gas retort refractories.

(iii) *Ceramics Investigations.*—A preliminary survey of Australian ceramic materials is proceeding. In South Australia this survey is being made in co-operation with the State Mines Department. As this work develops it will form the basis of investigations dealing with such matters as beneficiation of raw materials, selection of suitable materials for specific purposes, and other technical problems.

The Geology School of the University of Melbourne is co-operating in the development of facilities for the study of clay mineralogy which is an essential part of these investigations. Apart from the usual petrographic and mineralogical methods, use is being made of the techniques of dehydration analysis and thermal analysis, both of which are of significance in the study of natural clays.

4. *Foundry Sands Investigations.*—The chief work of this Section is directed to the investigation of sands and clays used in the foundy industry. In addition the Section has continued to provide an advisory service on foundry problems.

(i) *Moulding Sands.*—Surveys of moulding sands in Western Australia, New South Wales, and Queensland have been conducted in collaboration with the Mines Department of those States, and the results will be published in the near future. A number of firms are adopting a policy of decentralizing their activities and are establishing foundries in country districts. The Section has been called into consultation with these firms to select moulding sands in surrounding districts which have suitable characteristics and of which continuity of supply for some years is assured.

(ii) *Clays.*—Further work is being conducted on clays suggested as substitutes for American bentonite. One from the vicinity of Hobart has shown promise in preliminary tests and is being further investigated.

(iii) *Core Binders.*—The world-wide shortage of linseed oil which is extensively used as a core binder has caused inconvenience to the foundry industry. Information on substitute binders has been compiled and distributed to those directly concerned. Preliminary work has also been undertaken on the physical properties of cores in which substitutes have been used, and on methods of extending linseed oil.

5. *Physical Chemistry Section.*—Surface chemistry continues to be the chief topic of research, with particular reference to the principles governing the flotation process and their application in ore-dressing. The mechanism involved in the removal of grease and dirt from wool by scouring methods has also been investigated. In both the flotation and wool scouring investigations reagents of a high degree of purity were required; many of these were synthesized and sensitive methods were developed for their analysis.

(i) *Flotation Investigations.*—Improvements have been effected in a flotation method for recovering topaz, and products derived in this manner from a Tasmanian ore deposit possessed properties rendering them eminently suitable for certain uses in the ceramic industry. The method, however, must be further improved since it is affected by the hardness of the water available for the flotation. This adverse effect of permanent hardness of local water supplies also has an important bearing on the flotation of scheelite which is an important source of tungsten. Many attempts were made in these laboratories to concentrate scheelite from King Island ores by the conventional flotation circuits used abroad, but the recoveries were poor because of the calcium and magnesium salts in the available water. By the use of zeolite, the concentration of these salts can be sufficiently reduced to allow of the use of a simple reagent circuit containing only sodium oleate and sodium silicate. It remains to be determined whether this process can be adopted on the large scale.

(ii) *Scouring of Wool.*—The conventional method of scouring wool by solutions containing soap and sodium carbonate is effective only at temperatures above 120° F. These relatively high temperatures are necessary on account of the viscosity of the wool grease; only when the viscosity is small can the grease be emulsified and removed from the wool fibre. It would clearly be an advantage to be able to conduct the scouring operations at prevailing air temperatures, and a method was sought whereby the viscosity of the grease could be lowered sufficiently to enable this to be done. Small amounts of a solvent, added to the scouring bath in the form of an emulsion, have proved effective in increasing the mobility of the grease. The emulsion breaks down on, and then dissolves in, the grease, after which the mixture is emulsified. Small scale tests have proved encouraging.

Attempts have also been made to use a wide range of surface-active agents as detergents instead of soap. When soap is used, the solution must be alkaline and this causes some damage to the wool. While some of these appear to be of value for special purposes their superiority is not, in general, sufficient to outweigh increased costs compared with the customary procedure.

(iii) *Surface Areas of Solids.*—In a wide variety of reactions involving solids the behaviour of the system is intimately related to the state of division or surface area of the solids. An understanding of processes in which this is important requires a method of estimating the total area of the particles of solid; in equipment built in the Section this is done by making use of the direct relationship between the surface area of the solid and its power to absorb gases. Nitrogen gas is condensed on the surface of the solid at the temperature of liquid air; the surface area may then be calculated from the amount of gas removed by the solid. By this means attempts have been made to account for differences in behaviour of chemically similar materials. The suitability of different preparations of graphite and of pyrolusite for dry cell manufacture, and the effectiveness of thorium oxide as a catalyst for certain organic reactions, have been extensively studied in this way.

6. *Chemical Physics Section.*—Facilities for the application of several modern chemico-physical techniques have been added to the Section. These include a mass spectrometer, to be used in conjunction with isotopic tracer techniques, and for the analysis of complex mixtures of organic materials; an infra-red spectrometer, to be used largely for characterization of organic compounds, for the determination of molecular structure, and for complex organic analyses; a high-dispersion quartz spectrograph for the development of spectrochemical analytical methods and for spectrographic research; and a spectrophotometer for absorption spectroscopy. An X-ray spectrograph for use on problems concerned with the zirconium-hafnium separation and the rare earths has been constructed in the Divisional workshops.

An instrument laboratory providing facilities for the development and construction of electronic and mechanical instruments and for the construction of glass apparatus, has been established. A considerable variety of equipment for use in the investigations of this and other Sections of the Division has already been constructed.

(i) *Structure of the Wool Fibre.*—Collaboration with the Division of Physics on this project has continued during the past year. Confirmation of the electron microscopical evidence that there are three distinct components of the wool fibre has been obtained from X-ray diffraction investigations and a more detailed study of the matrix and fibrous components has been made. It has been established that the matrix consists of molecularly dispersed protein and that the fibrous component of the cortex is capable of fibrillation to a protofibril consisting of a linear aggregate of approximately isometric protein molecules. This is contrary to the current views on the structure of keratin fibres and indicates the necessity for a review of the structural chemistry of the wool protein.

(ii) *Structure of Cellulose.*—During recent years there has been some controversy concerning the existence of a limiting size of the fibrils formed when cellulose fibres break down by longitudinal cleavage under various treatments. A number of types of cellulose derived from cotton, hardwood, softwood and ramie fibre were mechanically beaten to disperse them in water and subsequently examined by new electron microscopical techniques. In every instance the smallest fibril observed was approximately 150 Ångström units in diameter. Moreover, in common with animal fibres, these fibrils appear to be linear aggregates of approximately isometric corpuscles, possibly molecules.

(iii) *Luminescent Materials.*—Theoretical and experimental investigations have been conducted on luminescent materials, which are used extensively in the lamp and radio valve industries. Technological advances in this field are dependent upon an understanding of the mechanism of the luminescent process which at present is only imperfectly understood. It has been established on theoretical grounds that the various possible mechanisms for the luminescent process in certain classes of material may be differentiated by experimental study of their behaviour under conditions of periodic excitation; experimental work on this basis is in progress. Spectroscopic measurements are being used to determine the various electronic energy states involved in this process, for it is when an electron passes from a higher to a lower energy state that light is emitted.

(iv) *Refraction Effects in Electron Diffraction.*—A new effect, interpreted theoretically in terms of a refraction of electrons due to the inner potential of a crystal, has been observed in an electron diffraction study of non-stoichiometric compounds. Through this effect, which appears to be associated with solids having crystal defects, it has been possible to explain the existence of anomalous line breadths and intensities in electron diffraction patterns, a matter of fundamental importance in the use of electron diffraction in the study of crystal structure and one which for many years has escaped explanation. Significant differences in the effect obtained from stoichiometric and non-stoichiometric phases of the one compound have been established; these are valuable in increasing our knowledge of the important group of non-stoichiometric compounds to which luminescent materials belong.

(v) *Miscellaneous.*—Further information concerning the nature of the compounds occurring at various stages of the processing of alunite has been obtained by X-ray and electron diffraction methods. Evidence concerning the physical state of the silica in alunite has also been obtained.

Three Australian bentonites have been studied by electron microscopical, X-ray and electron diffraction techniques and compared with Wyoming bentonite. Two of the Australia minerals (from Queensland and Western Australia) showed a preponderance of montmorillonite of which Wyoming bentonite is almost entirely composed.

An intensive X-ray crystallographic study of basic aluminium fluorides having different ratios of oxygen to fluorine was also made, and led to an unequivocal determination of their chemical structure. A considerable number and variety of short term projects were also investigated.

(*a*) *Electron microscopical investigation.*—Investigations undertaken at request included the further examination of iron oxide pigments and intermediates in relation to pilot plant production of these pigments; the examination of bacteria associated with the incidence of caries in teeth and the effect of these on the surface of the tooth enamel; a high-magnification metallographic study of steels subjects to various age-hardening treatments; fibrillations in hardwood pulps as a function of time of beating in processing for paper making.

(*b*) *X-ray and electron diffraction studies.*—Investigations undertaken at request included an examination of Lüder's lines in steel tensile test specimens, which has enabled the relationship between these lines and the regions and extent of deformation to be established; a study of certain manganese oxide minerals, resulting in the discovery of hydrated oxide phases not previously characterized; a study of the co-precipitation of berylium and aluminium in aluminium hydroxide; an attempt to find significant structural differences between normal and tension woods.

(*c*) *Spectroscopic studies.*—A method for the estimation of linolenic acid in safflower oil, a drying oil for paints, has been critically examined and estimations have been made for the Munitions Supply Laboratories of the Department of Munitions. The range of validity of a colorimetric method, involving a methylene blue complex, for the estimation of sulphonated surface active agents, has also been defined.

7. *Organic Section.*—Experimental work has been somewhat curtailed by the absence abroad of several officers, but steady progress has been maintained in the investigation of waxes and plastics, and of the mechanism of catalysis in heterogeneous systems. Work previously described on ketone waxes and furfural production has now been completed. Some new work based on the condensation products of acetone with ammonia, yielding a number of interesting products of potential commercial significance, has reached an advanced stage.

(i) *Sugar Cane Wax.*—This is a hard wax potentially available to the extent of several thousand tons per annum as a by-product of the Australian sugar industry. Although it is the equal of carnauba wax in polishing power, some defects will have to be eliminated to assure its commercial success. The initial steps in this improvement demand a knowledge of its chemical composition, and a considerable body of analytical data has been accumulated during the year. It has been found that the so-called "fat" which remains after an acid treatment to remove mineral matter consists largely of fatty acids derived from the breakdown of calcium phosphatidates during the process. It is probable that steam distillation under low pressure will provide a convenient means of removing these acids, and improve the quality of the wax. This analytical approach should lead to the separation of the wax into fractions having standard properties.

(ii) *Wool Wax.*—The potential commercial importance of wool wax led to its choice as a subject for investigation early in 1941; pressing problems arising out of the war, however, caused these investigations to be abandoned later in that year. This work has now been resumed, and in the last few months some success has met attempts to separate the numerous alcohols present in the wax. The method employed was a chromatographic separation of coloured derivatives, but owing to the complexity of the mixture of the alcohols this has, as yet, met with only partial success. If a simple method of separation can be devised, the pure alcohols should prove useful intermediates for the production of industrially important substances. Thus cetyl alcohol might be used for the manufacture of the wetting agent sodium cetyl sulphate. A cyclic molecular still has been constructed for use in this work.

(iii) *Investigation of Catalysis.*—Many organic chemicals are now produced as the result of reactions whose velocity has been speeded up by the presence of

catalyst. Although the activity of these catalysts has been vastly improved in recent years, the lack of a thorough understanding of their mode of action has proved a limiting factor in the selection of the type most suited to a particular reaction, and the prediction of its precise behaviour. In these investigations of some of the more fundamental aspects of heterogeneous catalysis, special emphasis has been placed on the kinetics of gas reactions over solid catalysts. The reactions studied to obtain basis data for this purpose were the oxidation of ethylene to ethylene oxide and the dehydration of 2, 3-butanediol to butadiene which was originally required for conversion to synthetic rubber.

In an order to measure the high rates of absorption of gas by the solid catalysts, special equipment has been built and is now being calibrated.

(iv) *Products of the Reaction of Acetone with Ammonia.*—Although acetone is one of the cheapest and most abundant of organic chemicals, there are many aspects of its chemistry which have not yet been fully worked out. A number of compounds are produced by its condensation with ammonia, and one of these has been studied in some detail. Previously its preparation involved a reaction time of several weeks and the yields were very poor. By conducting the reaction in a liquid ammonia medium and in the presence of an ammonium salt as a catalyst the Section has developed a method whereby the yield of this compound has been increased to 90 per cent. of that theoretically obtainable and the reaction time has been reduced to 18 hours.

The structure of this compound has been determined and a number of its derivatives have been examined. These are not only of considerable theoretical interest but of practical significance on account of their ready accessibility from cheap raw materials and their value as intermediates for the production of a number of other compounds which are not otherwise easily prepared. One of these, a diamine, has interesting possibilities for the production of synthetic waxes and of polyamide resins suitable for use as moulding powders.

(v) *Australian Alkaloids.*—Investigation of the alkaloids of the native flora, undertaken in collaboration with the Council's Division of Plant Industry and the Departments of Physiology of the Universities of Melbourne and Queensland, has been continued. It was evident early in the work that the number of alkaloids which might merit chemical examination (without regard to their pharmacological properties) would be large, and collaboration in this chemical work has been extended to certain University Chemistry Departments.

Most of the plants under investigation are members of the family Rutaceae which appears to be a fruitful source of alkaloids. Several representatives of a new group of alkaloids have been discovered and some progress made with the elucidation of their structure. The chemistry of some of these substances is proving of considerable academic interest.

Many of the species examined have failed to yield alkaloids in significant quantities, but *Melicope fareana, Rauwolfia canescens, Alangium vielosum* and *Atherosperma moschatum,* which are at present under examination, are proving promising sources of alkoids of considerable interest. Two further species yielding alkaloids which appear to belong to the same group as those derived from *Melicope* have been forwarded to the Universities of Melbourne and Sydney respectively for investigation.

(vi) *Plastics Investigations.*—(*a*) *Aniline-formaldehyde resins.*—Work has been continued with a view to eliminating some of the defects which has restricted the use of these resins, and to allow of advantage being taken of their superiority over phenol-formaldehyde resins in electrical properties and their low water absorption and transmission. One defect is the bulky gel-like form they assume during processing; it has been shown that this can be overcome either by the addition of electrolytes to flocculate the colloidal mass or by heating at 140° C. for short periods.

(*b*) *Tannin-formaldehyde resins.*—The extract of Mimosa bark obtained from certain South African species of Acacia and used in the tanning industry contains catechin which, like resorcinol, is a polyhydric phenol, and an investigation of its condensation products with formaldehyde is being made with a view to their use as cold-setting adhesives. It is probable that this work will later be extended to investigate the use of the commercial tannin extract obtained from *Eucalptus redunca.*

(*c*) *Resin fillers.*—During an investigation of the production of furfural from oat-hulls, quantities of lignocellulose residues became available. These have been used as fillers for phenolic plastics, and their effects on the mechanical and physical properties of the moulded products have been compared with commercial wood flour. Residues from the digestion of oat-hulls at low temperatures gave comparable results.

(vii) *Testing of Plastics.*—The water absorption of phenolic plastic mouldings has been examined in greater detail. It has been shown that, in general, the absorption conforms to a diffusion equation, but that deviations occur depending on the type of filler used. As a result of this work recommendations have been made to the Standards Association of Australia to assist in setting up Australian testing methods for plastics.

The vapour permeability of moulded fittings in electrical equipment assumes considerable importance under humid atmospheric conditions. Work is in progress to determine the vapour transmission through moulded specimens containing metal inserts previously coated with resins before moulding.

Work on mechanical tests for plastics has included an investigation on the Izod test.

8. *Biochemistry Section.*—Fellmongery and fermentation continue to be the chief subjects of research, and several projects connected with the former have reached the stage of pilot-scale investigations, and in some instances are being conducted in fellmongeries. The six-monthly distribution of circulars commenced in 1946 has been continued, and by this means and by visits of officers to most fellmongeries the industry has been kept informed of the trend of fellmongering research.

(i) *Fellmongery.*—The chief lines of work have been concerned with the loosening of wool from skins by various agencies, and with the recovery of wool from heads, shanks, and skin pieces for which no entirely satisfactory method has been available.

(*a*) *Wool loosening by chemicals.*—Wool can be loosened from the skin by treatment with certain chemical agents and the mechanism of the process is being investigated. Such treatments frequently cause damage to the wool and a chemical method involving the estimation of sulphydryl groups arising from degradation of the keratin has been developed and is now being critically examined to determine its accuracy in assessing this damage. Chemical depilatories containing lime cause appreciable damage to the wool and a modified painting process has been developed which involves soaking in a dilute solution of sodium carbonate and subsequently treating with sodium sulphide. The method has been subjected to pilot-scale tests and has proved a considerable advance over any previous method in that the wool has been effectively loosened with scarcely any damage to the wool. With slight modifications this method has already been adopted in some fellmongeries.

(*b*) *Wool loosening by enzymes.*—The depilation of sheep skins can be effected after treatment with a paint containing certain enzymes which are produced by a variety of biological materials. *Aspergillus oryzae* and *A. parasiticus* have been found to produce an active enzyme; the former has been chosen for a more detailed study of its mode of action and of the optimum conditions leading to ultimate depilation.

(*c*) *Wool loosening by bacteria.*—Further samples of sheep skins have been obtained from various parts of the world for investigation of their bacterial flora, and recent examinations of samples from Canada and the United States of America has resulted in the isolation of another species of bacterium capable of wool loosening in pure culture.

(*d*) *Recovery of wool from skin pieces.*—The investigation on a pilot scale of the production of the protease derived from *Aspergillus oryzae* has been continued and the major difficulties appear to have been overcome. The time of growth which will give active extracts has been considerably reduced, and bacterial contamination which can lead to considerable difficulties has been practically eliminated. Work has also commenced on the production of the enzyme in synthetic media.

Pilot-scale tests of the recovery of wool from skin pieces have been successfully conducted in collaboration with the Chemical Engineering Section, and the present work is designed to ascertain the optimum conditions for high recovery without significant wool damage.

(ii) *Industrial Fermentation.*—(*a*) *Lactic acid.*—Work on the production of lactic acid from whey by *Lactobacillus bulgaricus* has been continued, and attempts have been made to improve the yield by supplementing the sugar in the whey by the addition of hydrolysed starch, unrefined cane sugar, and molasses. In order to render production less dependent on the availability of whey, other substrates which are readily available are being sought as substitutes.

(*b*) 2, 3-*Butanediol.*—Investigations of the production of 2, 3-butanediol from wheat which were initiated in connexion with synthetic rubber investigations have been continued with a view to determining the mechanism of its production by *Aerobacillus polymyxa*. Differences in the ease with which fermented mashes can be filtered have been found to be related to the formation of polysaccharide slimes which vary according to the strain of the organism employed. These difficulties in filtration have now been largely resolved. The effects of sporulation of *A. polymyxa* on its nutritional requirements and the effect of using different strains for the production of mashes for fermentation have been investigated in connexion with the production of 2, 3-butanediol and ethanol.

The hydrogenlyases of *A. polymyxa* and *Escherichia coli* have been shown to be composite enzyme systems whose nature is being further investigated.

(*c*) *Survey of Australian microflora.*—A survey of Australian micro-organisms and their products of metabolism has been commenced with a view to exploring the possibilities of developing new fermentations of industrial interest.

9. *Chemical Engineering Section.*—(i) *Research in Unit Processes.*—The Chemical Engineering Section has a twofold function; it is responsible for pilot-scale development of processes originating in other sections of the Division, and it has the no less important task of carrying out investigations aimed at the advancement of fundamental chemical engineering knowledge. Such investigations involve the study of the mechanism of unit operations with the object of determining the precise mathematical relationships between the various factors involved and ultimately of improving the efficiency with which these operations can be conducted.

During the early years of the life of the Division the urgency of the demand for pilot-scale investigations of processes developed by the Division greatly restricted the amount of more fundamental work that could be undertaken. During the year under review, it has been possible to formulate plans for research of the latter type on problems of heat transfer, filtration, and distillation. During this period also a guest worker spent some six months in the laboratory studying the fundamental aspects of solvent extraction processes, and it is proposed to appoint an additional officer to the Section to enable this investigation to be continued.

Two members of the staff of the Section are gaining experience in chemical engineering research laboratories in the United States, another is carrying out post-graduate academic work in England; the return of these officers should give additional impetus to the Section's projected programme of chemical engineering research.

(ii) *Building for Process Equipment.*—The Section has now accumulated a wide range of pilot-scale chemical engineering process equipment. Owing to limitations of space it has been necessary in the past to store this equipment and set up individual units from time to time as required for specific pilot plant investigations, the equipment being dismantled at the conclusion of each period of operation. During the year an additional building suitable for housing chemical engineering equipment has been erected in which much of the pilot-scale plant will be set up permanently, so that each unit will be available for operation at short notice. Installation of plant in this building is now under way.

(iii) *Production of Furfural from Agricultural Wastes.*—The pilot scale investigation of the production of furfural by the acid digestion of agricultural waste materials has been completed and the data required for the design of a commercial-scale plant have now been assembled. This work is fully described in papers which are in the press.

Considerable interest has been shown by various industrial firms in this work and in the possibility of undertaking furfural production, and there are good prospects that the Section's work in this field will find application.

(iv) *Production of Chromic Anhydride.*—Developmental work on the pilot plant for production of chromium salts from chromite ore by an acid process has almost been completed. It is believed that the process which has been evolved offers substantial advantages over the conventional alkali fusion method. In order to obtain data required for the design of full-scale plant and for calculation of costs the process is being operated on a continuous basis over a period of several months.

The operation of the pilot plant has been demonstrated to the representatives of a number of industrial firms.

(v) *Recovery of Wool from Sheepskin Pieces by Proteolysis.*—The recovery of wool from heads, shanks, and skin pieces by the digestion of the skin by means of an enzyme derived from a mould has been studied in collaboration with the Biochemistry Section. Pilot-scale production of the mould and the use of the extracted enzyme for the subsequent treatment of the skin pieces have been continued with satisfactory results. Most of the work now devolves on the reduction of the time required for these operations, and in refinements of technique.

(vi) *Instrumentation.*—The efficient operation of chemical engineering plant calls for the application of the best techniques of instrumentation; particularly difficult instrumentation problems arise in the design and operation of equipment for chemical engineering research. In order that the research staff may have the

benefit of assistance in such matters, an experienced instrument technician has been appointed to the Section.

(vii) *Advisory Services.*—Members of the Section have devoted a considerable proportion of their time to advising officers of other Sections of the Division regarding the problems likely to be encountered in transferring specific processes of potential industrial value from laboratory operations to commercial-scale processes. Similarly, attention has been given to answering inquiries from representatives of various industrial firms in connexion with the design of chemical engineering plant.

10. *Publications.*—The following papers have been published during the year:—

Clay, J. L. (1946).—Further studies of the industrial development of the Freney-Lipson process. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 256-68.

Cowley, J. M., and Patterson, M. S. (1947)—X-ray diffraction studies of yielding in mild steel. *Nature* 159: 846.

Cowley, J. M., and Rees, A. L. G. (1946).—Refraction effects in electron diffraction. Ibid. 158: 550.

Cowley, J. M., and Rees, A. L. G. (1947).—Refraction effects in electron diffraction. *Proc. Phys. Soc.* 59: 287.

Dixon, P. (1946).—The solubility of silica in alkaline ammonium fluoride. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 311-6.

Farrant, J. L., Mercer, E. H., and Rees, A. L. C. (1947).—The structure of fibrous keratin. *Nature* 159: 535.

Hanna, K. R. (1946).—Investigation of methods of determining the weight or average thickness of tin or tin-coated copper and brass. *Amer. Soc. Test. Mat.* 142: 35-7.

Hanna, K. R., and Worner, H. W. (1946).—Preparation of titanium powder. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 449-54.

Hergt, H. F. A., Rogers, J., and Sutherland, K. L. (1947).—Principles of flotation. Flotation of cassiterite and associated minerals. Amer. Inst. Min. Eng., Tech. Publ. 2081, Min Tech.

Martin, R. J. L. (1946).—The analysis of the hydrocarbon gases by fractional distillation with especial reference to cracked tar gases. Coun. Sci. Ind. (Aust.), Bull. 197.

Mercer, E. H., and Rees, A. L. G. (1946).—The structure and elasticity of the cortex of keratin fibres. An electron microscope study. *Aust. J. Exp. Biol.* 24: 175.

Murray, K. E. (1946).—The catalytic dehydration of the amyl alcohols of fusel oil with a kaolin catalyst of high activity. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 438-41.

Plante, E. C. (1947).—The flotation of fluorite. Amer. Inst. Min. Eng., Tech. Publ. 2163, Min. Tech.

Rees, A. L. G. (1947).—Recent physico-analytical techniques. *Aust. Chem. Inst. J. Proc.* 14: 23-36.

Rogers, J., and Sutherland, K. L. (1947).—Principles of flotation. Activation of minerals and adsorption of collectors. Amer. Inst. Min. Eng. Tech. Publ. 2082, Min. Tech.

Scott, T. R. (1946).—The chemical composition of natural and synthetic cryolite. *J. Coun. Sci. Ind Res.* (Aust.) 19: 442-8.

—— (1946).—Preparation of core ingredients of searchlight carbons. Coun. Sci. Ind. Res. (Aust.), Bull. 200.

—— (1947).—The solubility of lead fluoride in solutions of aluminium fluoride. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 114-21.

Sutherland, K. L. (1946).—The surface areas of fine powders. *Aust. J. Sci.* 8: 155.

Wylie, A. W. (1946).—Deuterium or heavy hydrogen. Ibid. 9: 43-50.

XVI. RADIOPHYSICS.

1. *Introduction.*—During the past year the activities of the Radiophysics Laboratory have been concentrated on radio researches of a fundamental character, on radio meteorological problems, and on development work aimed at the application of radar techniques to civilian uses. Perhaps the most important results of this work have been—(i) An advance in knowledge of radiations emitted at radio frequencies from the sun and the universe. (ii) The opening up of a promising new avenue of research in the radio meteorological field which will provide basic information on the physics of cloud formation and may lead to the practical possibility of stimulating rainfall by artificial means. (iii) The completion and successful demonstration of new radar aids to civil aviation.

The year has been a continuation of the process by which members of the staff have obtained research experience overseas. These opportunities have occurred largely through the Council's scholarships and partly as a result of personal initiative. At present there are ten officers abroad acquiring further experience and acquainting themselves with new techniques.

2. *Extraterrestrial Noise.*—(i) *Solar Noise.*—Since radio waves are similar to heat and light waves but of longer wavelength, it should be possible to receive thermal radiation from the sun in the radio spectrum. Early attempts to detect the radiation failed through lack of sensitivity of the equipment, but it was detected in America in 1942. The first experiments were performed on wavelengths of 3 and 10 centimetres and showed an intensity a little greater that that calculated from the ordinary laws of radiation, assuming it came from the surface of the sun. Later measurements here and elsewhere have brought out two interesting facts: on longer wavelengths an intensity greatly in excess of the expected value is obtained from the "quiet" sun, and this intensity itself varies with time over a wide range.

The study of radio noise is a new branch of astrophysics, and when the nature of the radiation is more clearly understood it is expected to yield valuable information about the processes occurring in the sun. Experimental work undertaken to date has isolated a number of phenomena which may be described as follows:—

(*a*) *Thermal radiation.*—The temperature of the photosphere, or visual disc of the sun, is known to be 6,000° K. The measurements referred to above indicate that on microwavelengths the noise source has a temperature of the same order. At 200 Mc/s, however, the temperature of the source of steady radiation from the quiet sun is nearer a million degrees Absolute. These results suggest at once that the noise does not originate in the photosphere but in some other region in the sun. There is evidence from optical data that the sun's corona is at a temperature of a million degrees Absolute, and it has been shown that the 200 Mc/s radiation does in fact come from the coronal regions. By measurement of noise intensity on successively higher radio frequencies, it is possible to obtain the temperature at lower and lower levels in the corona, and an extensive series of measurements has given valuable data about the constants of the solar atmosphere.

(*b*) *Enhanced solar noise.*—If noise from the sun is observed continuously, it is found that when the sun is disturbed by large sunspots, irregular increases of radio noise can occur lasting for periods of several days at a time. The changes of intensity are many thousandfold, indicating that this noise must have its origin in an electrical and not a thermal phenomenon. Experiments have shown that a close correlation exists between noise intensity and sunspot area, while precise direction-finding methods have confirmed that the source coincides in position with major sunspots.

(*c*) *Bursts.*—The third phenomenon observed is the occurrence of short bursts of noise of duration from 1 to 60 seconds and of magnitude comparable with sunspot noise. The bursts have been located as having their origin in the sun, but they have not yet been correlated with visual phenomena. When observed on a series of different radio frequencies, it is found that in the majority of cases a burst occurs on one frequency but not on the others. This leads to the conclusion that the noise comes from isolated levels in the corona. In a few cases, however, the same burst is observed on a number of adjacent frequencies. Almost invariably it appears first at the highest frequency and, after an interval of a few seconds, at lower frequencies. The phenomenon is being made the subject of further experimental work.

(*d*) *Outbursts.*—Outbursts differ from bursts in magnitude and duration; their intensity is greater by several hundredfold and they last for several minutes at a time. They were first observed by experimenters overseas, and their occurrence has been associated with the appearance of flares on the sun's disc. Observation of outbursts over a range of frequencies has shown that they can appear on a number of adjacent frequencies but, unlike bursts, with a delay of several minutes instead of seconds between them. This has led to the suggestion that their origin is connected with the movement of the disturbing agency outwards through the sun's atmosphere, possibly in a stream of particles such as those which give rise to aurorae and magnetic storms when they reach the earth.

Most of the work carried out to date in Australia and overseas has been in the range of 1-10 centimetres. Equipment is now being constructed for observation of solar noise on millimetre wavelengths where the absorption and emission spectrum of elements in the sun becomes important.

(ii) *Cosmic Noise.*—The arrival of radio noise from other parts of the universe has been known for a considerable time. Until recently it was thought to have its origin in inter-stellar space rather than in stellar bodies. Measurements on the constellation Cygnus, however, suggest very forcibly that in this particular case the accepted theory does not hold. It appears that a source of noise exists in that constellation, having characteristics similar to those of the sun but of infinitely greater power.

3. *Superrefraction.*—In the previous report, reference was made to the collaboration which took place between the Division and the armed forces in the collection of data on superrefraction over a wide region in Australia and New Guinea. The analysis of these data was completed during the current year; a report which gives an account of the places and times of occurrence of superrefraction and their relationship to general and local weather conditions has been written.

The work has focused attention on several meteorological phenomena which have an important influence on superrefraction in Australia. Two of them have been the subject of detailed experimental investigation.

(i) *Investigation of the New South Wales "Coastal Front".*—Intense superrefraction has been found to occur around the coast of New South Wales during weather conditions which have become known to meteorologists as the "coastal front". Some quantitative measurements of both the radio and meteorological factors involved have been made in the past; during the current year, careful plans were laid to complete the measurements. However, the season was abnormal, the "coastal front" did not develop in the expected manner, and the work has been postponed until next summer.

(ii) *Investigation of Inland Radiation Inversion.*—On winter nights the surface of the earth loses heat by radiation and cools the lower levels of the atmosphere by contact. Under calm conditions on a flat plain, the rate of cooling of the atmosphere at different levels gives valuable information concerning the transfer processes at work in the atmosphere. Although prompted by radio considerations, the problem is essentially a meteorological one and was attacked from this point of view in a series of observation at Hay (New South Wales). The analysis of results is nearing completion. A surprising result is that even at Hay the ground is not sufficiently flat to allow the simple conditions to develop, the slope of 1 foot in a mile being enough to allow horizontal movement of the air which upsets the determination of the transfer constants.

4. *Ionospheric Investigations.*—A detailed investigation is being carried out on the fine structure of the ionosphere and the small changes which occur in its characteristics. This is being done at vertical and oblique incidence, using new techniques developed during the war. Accurate recordings of the variations in virtual height and echo intensity at vertical incidence are already being made. This investigation will shortly be handed over to the Radio Research Board.

5. *Middle Atmosphere Investigations.*—With the intention of further investigating phenomena observed in the atmosphere on war-time radar sets, a 120 kilowatt pulse transmitter is operating on a frequency of 18 Mc/s. No middle atmosphere echoes have yet been observed, but sporadic echoes from the 100-200 km. and the 1,000-2,000km. region are being studied to determine the nature of the scattering centres and the agency producing them.

6. *Radio Meteorology.*—Radio Meteorology is concerned with studies involving both radio and meteorological phenomena, two examples of which are superrefraction and the scattering of radio waves by water drops and ice particles. Initially, these subjects were studied mainly from the radio point of view, but the meteorological problems have become so interesting in themselves that they now form the principal part of the study.

The Division's programme is divided into two main parts—experimental studies of the processes at work in the formation of rain and a theoretical attack on the problem of cloud physics.

(i) *Studies of Rain Formation.*—The process by which rain is formed in clouds has always been obscure. A number of theories exist but there is great difficulty in obtaining quantitative data, and it may be many years before any one of them can be substantiated.

Following a suggestion made in America, experiments have begun on the artificial stimulation of rainfall; they have been successful in producing rain from towering cumulus. This success is likely to be of great practical importance to Australia, and it has also given a great simulation to experimental work by allowing cloud investigations to be carried out under controlled conditions. The experiments lend strong support to one particular theory of rain formation—that of Bergeron—and therefore give a very good lead as to the direction in which further investigation should take place.

Owing to the absence of measuring instruments, no quantitative data are available on the physics of the process. It is expected that substantial progress in the understanding of rain formation will not take place until instruments have been built and a long series of measurements completed.

(ii) *Cloud Physics.*—A summary of existing ideas on the subject of cloud physics has been made and, stimulated by the work on the artificial production of rain, a theoretical attack has begun on problems associated with the formation of water drops and ice particles in clouds. A theory is being developed on the distribution of drop sizes in newly formed clouds, and the forecast distribution is found to be in good agreement with that observed in certain overseas measurements. Work is also being carried out on the coagulation of falling drops and on the flow pattern around drops which fall with a velocity faster than that represented by Stokes Law.

(iii) *Barometric Method of Determining Height.*—A relatively simple method of determining the height above sea level of an unknown station from barometer readings taken at the site has been developed, and the method applied to a number of stations of known height with most encouraging results. The proposal has been placed before the survey authorities in order that they may develop it further and apply it to particular survey problems should such application prove desirable.

7. *Mathematical Physics.*—The Mathematical Physics Section is engaged on theoretical work associated with the investigations into radio meteorology, radio propagation, the scattering of radio waves and solar noise.

(i) *Radio Wave Propagation.*—Radio propagation work has been mainly concerned with the theory of superrefraction and an extension of the numerical study of ground-based trapping. The use of wave optical theory has been applied to distant parts of the radiation field, but in addition it has been found possible to extend the use of geometrical principles of optics to include diffraction effects near foci. A basic extension of the mathematical theory of foci to include conditions of spherical aberration has been completed, and the results are being applied to the analysis of optical fields.

The solution of two other problems awaits the arrival of a special type of calculating machine—the estimation of the characteristic waves for different refractive index structures, and the application of generalized phase-integral methods. The former requires the solution of certain types of differential equation, while the later calls for systematic study and tabulating of both the Gamma function for complex values of the argument and the parabolic cylinder functions for complex values of the order.

(ii) *Antenna Theory.*—Electromagnetic radiation problems have been attempted, and an antenna theory of the properties of probes within waveguides has been derived. The methods developed are applicable to the case of resonant slots and to radiation from waveguides and cavities into open space through such slots.

(iii) *Rain Formation.*—Studies associated with rain formation are still in their early stages. Their object is to estimate theoretically the life history of a collection of drops falling through the atmosphere. The factors of importance are: the rate of diffusion towards and away from the drop; the flow of heat towards or away from it; the surface drag and consequent circulation within the drop; its deviation from sphericity; and its collision cross section. As long as the critical Reynolds number is not exceeded, it is possible to calculate the flow pattern around the falling drop, from which most other factors can be derived.

The determination of the flow pattern for drops of different sizes falls into three classes. For very small Reynolds numbers, Stokes Law holds, so that the flow can be estimated analytically; for very large drops the flow depends upon the boundary layer, and this flow can again be determined analytically. At intermediate values of Reynolds numbers the flow must be estimated numerically and the relaxation process is being applied.

(iv) *Scattering of Radio Waves.*—Following a previous study of scattering of waves by cylinders, spheres and ribbons, an attempt is being made to calculate the scattering of plane waves by discs of diameter comparable with the wavelength. The theoretical results will be compared with the results of the usual diffraction theory to estimate the validity of the latter.

(v) *Solar Noise.*—Calculations are proceeding in an effort to obtain a reliable estimate of the magnitude of the "limb brightening" effect; the existence of this effect has not been established experimentally, and there is some theoretical doubt about its existence which it is hoped to clear up.

8. *Vacuum Physics.*—The work of the vacuum laboratory has been reduced by the departure of staff for study overseas and, pending their return, the amount of experimental work in vacuum physics is small. The laboratory equipment and technical personnel are being retained and their services put at the disposal of other Divisions of the Council and of departments of the University.

(i) *Gas Discharge Work.*—The investigation initiated last year on the minimum electrical breakdown voltage of gases at high frequencies has been completed. The results show good agreement with existing theories. Further work is in hand for an attack on the mechanism of initiation and decay of discharges, from which it is expected to obtain information on such factors as diffusion, recombination and attachment, as well as on the process of ionization in a high frequency field.

(ii) *Acceleration of Electrons.*—High energy electrons are being obtained by acceleration in both single and multiple resonant cavities. A single cavity operating at a frequency of 1,200 Mc/s gives a million volt electron beam which is being used to generate high-intensity pulsed X-rays. These are generated in a simple compact equipment and are suitable for radiographic and therapeutic purposes. The work has progressed to a stage at which it can be taken over by a manufacturer. Considerable interest in the development has been expressed overseas, and a useful commercial product may result.

(iii) *Proton Acceleration.*—Work on proton acceleration proceeded to a stage at which a satisfactory voltage was developed in the accelerating cavity and an intense ion source produced, based on an idea originating in the Physics Department of the University of Sydney. No actual acceleration of protons has yet been attempted, however.

(iv) *Associated Research.*—The facilities of the vacuum laboratory are being used by other Divisions based at Sydney, and the Division of Physics has assisted in staffing the laboratory by making available an expert glass technician and a research officer for work on the linear accelerator.

The laboratory is also being used by departments of the University for joint or independent research. The Electrical Engineering Department is carrying out an investigation on the de-ionization of gas discharges, and the Physics Department is planning to engage in a related programme of work. The Physics Department is also using the multiple-gap accelerator for X-ray production to examine nuclear phenomena.

9. *Measurements and Standards.*—The collaborative programme agreed upon with the Division of Electrotechnology has been continued. This aims at transferring, ultimately for permanent retention within the Division of Electrotechnology, such ultra high-frequency techniques developed during the war as are applicable to the development and maintenance of

standards in this field. Although the work has been carried out under the direction of an officer of the Radiophysics Division, the majority of the scientific staff in this group have been made available by the Division of Electrotechnology.

(i) *Noise Generators.*—A study of the errors inherent in the use of temperature-limited diode as an absolute source of noise power has shown that these devices can be relied on up to frequencies in the region of 200 to 500 Mc/s, and several such generators have been built and used. Extension of the frequency range up to 3,000 Mc/s is anticipated using a diode built in the form of a concentric line.

Thermal noise generators employing hot filaments are at present used in the region above 500 Mc/s. The effective noise temperature of such a filament is determined by comparing its noise output at 30 Mc/s with a standard diode noise generator. This eliminates errors associated with optical and other methods of determining the temperature of small filaments.

(ii) *Power Measurements.*—The main effort has been directed towards the calibration of the power output of standard signal generators when feeding a matched load. Thermistor mounts and bridge circuits have been developed, and equipment now exists for the accurate measurement of power from a few microwatts to a few tens of milliwatts over the frequency range 24 to 1,500 Mc/s.

(iii) *Impedance Measurements.*—Work has been carried out to improve the accuracy of impedance measurement by means of the slotted type of coaxial line. Attention has been directed chiefly towards improving the concentricity of inner and outer conductors and eliminating reflections caused by mismatch at the ends of the line where the diameter requires to be reduced for connexion to solid coaxial cables. A slotted line has been constructed on which a standing wave ratio of less than 1.02 can be observed at any frequency from 60 to 220 Mc/s.

(iv) *Frequency Measurements.*—Methods have been devised for the accurate measurement of frequency up to several thousand megacycles per second. The technique compares the harmonics produced by a stable low frequency oscillator with the unknown high frequency signal. By successive applications of this technique, the frequency of a 24,000 Mc/s oscillator has been measured in terms of a standard 1 Mc/s quartz crystal oscillator.

Optical interference methods have been devised for the direct measurement of wavelength in the centimetre and millimetre wave regions.

10. *Civil Aviation.*—The Division has continued to play a part in the development of radar aids to civil aviation, and, in order to keep in touch with activities overseas, a representative attended meetings of the Technical Committee on Radio Navigation organized by the then Provisional International Civil Aviation Organization at Montreal in October. 1946.

The experimental projects undertaken by the Division consist of two navigational aids for use in aircraft and two ground radar systems to assist in the control of traffic. Most of the effort in the past year has been put into full-scale trials of the navigation equipment over a test route from Melbourne to Sydney, demonstrations to the International Conference at Ottawa, and provision of a working system to Royal Air Force Transport Command in England.

(i) *Distance Measuring Equipment.*—Development work on the Australian Distance Measuring Equipment has been completed, and experimental ground stations have been installed, in co-operation with the Department of Civil Aviation, at Melbourne, Yass, and Sydney. The airline companies—Trans-Australia Airlines and Australian National Airways—are conducting operational trials of the Distance Measuring Equipment by flying with it in passenger and freight aircraft over this route. The tests have provided valuable operating data and allowed the form of the Distance Measuring Equipment to be finalized for production. The first stage of the work is complete, and effort will now be concentrated on the more general problem of using distance measurement as part of a complete navigational system.

(ii) *Multiple Track Range.*—The Multiple Track Range is a pulse-type radial-track guide system for providing a number of accurately defined tracks which a pilot can follow into, and out of, an airport by means of an indicator on his instrument panel. The Australian Radar Range, unlike existing radio ranges, is unaffected by mountainous terrain and has proved quite successful. At the request of P.I.C.A.O., the set was demonstrated by officers of the Division in Ottawa in September, 1946, in co-operation with the Canadian National Research Council and the Royal Canadian Air Force. Over a hundred international delegates flew in two aircraft which were fitted for the demonstration. Subsequently, at the Conference itself, the continued testing and development of the Australian Radar Range was definitely encouraged.

At the request of the Royal Air Force Transport Command, the equipment used in the demonstration at Ottawa was then moved to their Development Unit at Brize Norton, England, with one of the Division's officers to supervise its installation and instruct personnel in its use. Transport Command, to date, have carried out extensive tests of the equipment as a short distance navigational aid and as an aid to final approach to the runway. The results have proved successful and a request has been received for more equipment to be sent to the United Kingdom for more extended tests of a complete traffic handling system.

(iii) *Airways and Approach Control Radar.*—The two aspects of ground supervision of air traffic of most interest under Australian flying conditions are the safety of aircraft along the airways and in the airport approaches. Airways control involves a knowledge of the position of all aircraft proceeding along the air routes and provision for their safe separation, while approach control involves a direct and close supervision of all aircraft, in the immediate vicinity of the airport, which are about to land or take off, particularly under conditions of poor visibility. These two requirements are being met by the use of radar systems known respectively as Airways Control and Approach Control Radar.

(*a*) *Airways Control.*—An airways Control radar system has been developed and installed for trial in Sydney. It consists of a high-power radar set at George's Heights which detects aircraft along the air routes within a distance of 100 miles. This information is then transmitted over a radio link and received at Mascot, eight miles from the radar site. There an operator works an automatic plotter which displays to the Control Officer the positions and tracks of all aircraft in range of the radar set. The system has been operating experimentally for several months, and when in regular use is likely to prove a valuable aid to flying safety.

(*a*) *Approach Control.*—An Approach Control radar system has been developed and installed at Mascot. Laboratory experiments with the equipment have been completed, and since January, 1947, the system has been maintained and used regularly by the Department of Civil Aviation.

The Approach Control radar system consists of a set on the airfield which detects all aircraft within reasonable height limits up to twenty miles from the airport. The radar display is transmitted by underground cable to the control tower where an operator works an automatic plotter identical with that used

for Airways Control. In this way the control officer has a display of the tracks of all aircraft in the immediate vicinity of the airport.

The method of displaying the airways and approach radar tracks is, at present, unique in Australia. It is referred to as "Daylight Display" and has a number of useful features. The tracks appear as dark marks against a brilliantly lighted background, so that the Controller can see under any lighting conditions the position and direction of movement of all aircraft. The tracks also fade away at a predetermined rate so that the display clears itself continually as aircraft leave the area or come in to land.

11. *Radar Aids to Ground and Aerial Survey.*—The Division has acquired an American equipment known as "Shoran" which is being adapted for experiments on the measurement of long base lines and which can eventually be used for the control of photographic survey aircraft.

A Radar Triangulation Sub-Committee has been formed to advise the National Mapping Council on the application of radar to distance measurement. The Sub-Committee has asked that special attention be paid to the problem of radar triangulation, and experiments are accordingly being conducted to determine the best method of applying Shoran to this measurement. From the work undertaken to date, it is known that accuracies of several parts in 104 are possible; a figure of one in 105 may be achieved in the near future.

An investigation of the variation of velocity of radio waves in the lower atmosphere due to changing atmospheric conditions has shown that they will affect the radar results to an appreciable extent. Measurements of the change in temperature and pressure of the air and water vapour content over long paths have shown that satisfactory corrections for these effects are possible.

12. *Radio Control of Model Aircraft.*—As an aid to aeronautical and meterological research, the Division has started to develop radio equipment for the remote control of model aircraft by radio. This work is part of a joint programme being undertaken in collaboration with the Council's Division of Aeronautics and with the Aeronautics Department of the University of Sydney. On the aeronautical side, it is expected to lead to techniques for the study of aircraft in free flight under conditions which cannot be similated in the wind tunnel and with models which do not have to be large or safe enough to carry a pilot. For meterology, it is expected that a flying model can be used for investigating detailed meterological phenomena, e.g. rain clouds and also for routine meterological measurements.

13. *Work for the Services.*—The trials of the only remaining service equipment on the Division's programme have been completed in collaboration with the Royal Australian Air Force. The equipment is a radar set of a new high-powered type of which two prototype models were nearly complete at the end of the war. The set has been used extensively as part of the Airways Control Radar system for civil aviation purposes.

14. *Publications.*—In common with other laboratories, difficulty has been experienced in getting material published in a proper form. The manuscript of a text book of radar was completed in July, 1946, as a joint work by several members of the staff. The issue of the book, however, has been delayed by printing difficulties and may not appear until next year. Similarly, with scientific and technical papers. Ten papers have been accepted by overseas journals but are still awaiting publication.

The following list gives the more important of the internal reports which have been issued in mimeographed form:—

Beard, M., and Piddington, J. H. (1946).—A multiple track radar range. RPR.6.

Blackett, L. R., and Kaiser, T. R. (1946).—Field distribution between sharply pointed electrodes measured by the electrolytic tank. RPR.30.

Bracewell, R. N. (1946).—Step discontinuities in disc transmission lines. RPR.27.

—— (1946).—The L-brand thermistor power meter. RPR.28.

—— (1946).—Dissipated transductors treated graphically. RPR.32.

—— (1946).—Disc transmission lines in microwave apparatus. RPR.33.

Burgmann, V. D. (1946).—Airways and airport traffic control: Australian AWC and ATC radar. RPR.8.

Cooper, B. F. C., and Hindman, J. V. (1946).—An improved range measuring circuit. RPR.20.

Dewsnap, G. C. (1946).—Output pulse transformers for radar sets. RPR.36.

Downes, J. G. (1947).—Interim report on operation of D.M.E. and M.T.R. equipments—Sydney to Melbourne trials. RPR.69.

Fraser, D. B. (1946).—Spectrum of noise from temperature limited diodes. RPR.25.

Freeman, Joan M. (1946).—Investigation of electrical breakdown of gases at low pressures in the microwave region. RPR.50.

Fry, J. A. (1947).—The reproduction of transients in radar receivers. RPR.61.

Hibbard, L. U. (1947).—Remote radio control. RPR.57.

—— (1947).—A composite radar, remote control, and telemeter equipment. RPR.63.

Kaiser, T. R. (1946).—An automatic polar diagram recorder. RPR.5.

Kaiser, T. R., and Blackett, L. R. (1946).—Impedance of a slot dipole near a reflecting surface. RPR.34.

Kerr, F. J. (1946).—A survey of radio superrefraction on 200 Mc/s in the coastal region of Australia. RPR.37.

Kraus, E. B. (1947).—Theories of drop and crystal formation. RPR.54.

Mills, B. Y. (1946).—Some limitations in cathode follower design. RPR.16.

—— (1946).—Circuit design details of L-band thermistor power meter. RPR.39.

Molloy, D. B. (1947).—A method of frequency modulation of resistance capacitance oscillators. RPR.62.

Mulholland, E. B. (1947).—Test equipment for multiple track range equipment Mark I. RPR.59.

Pearcey, T. (1946).—Modern trends in computing machines. PRP.52.

Piddington, J. H., and Cooper, B. F. C. (1946).—The Australian distance indicator. RPR.7.

Piddington, J. H., and Reed, J. W. (1946).—A computor for determining aircraft position with a distance measuring radar set. RPR.1.

Treharne, R. F. (1946).—Radar aids to Australian airways control. RPR.18.

Treharne, R. F., Bennett, E., and Everitt, M. (1946).—Air transportable centimetric height finding radar (CMH Mk. I.) interim technical manual. Parts I. and II. RPR. 17.

Wirsu, O. L. (1946.).—An electromechanical aerial field calculator. RPR. 12.

—— (1946).—LW/AWH Mark II. light weight air warning and height finding ground radar. RPR. 41.

The following papers have been published in outside journals:—

Bowen, E. G., Gooden, J. S., and Pulley, O. O. (1946).—Application of pulse techniques to the acceleration of elementary particles. *Nature* 157: 840.

Hibbard, L. U., and Piddington, J. H. (1947).—A precision exponential potentiometer. *J. Sci. Instrum.* 24: 92-4.

Kraus, E. B. (1947).—Earth sciences. *Aust. J. Sci.* 9: 180-3.

Kraus, E. B., and Squires, P. (1947).—Experiments on the stimulation of clouds to produce rain. *Nature* 159: 489.

McCready, L. L. Pawsey, J. L., and Payne-Scott, Ruby (1946).—Radio frequency energy from the sun. Ibid. 157: 158.

Pawsey, J. L. (1946).—Observation of million-degree thermal radiation from the sun at a wavelength of 1.5 metres. Ibid. 158: 633.

XVII. TRIBOPHYSICS.

1. *Introduction.*—The work of this Section now falls into three main groups: the first dealing with friction, lubrication, and wear of solid surfaces; the second with the structure and properties of solids, especially of metals; and the third with the mechanism of explosion.

Lubrication, and in particular boundary lubrication, is essentially a surface effect. Any advance in our knowledge of this subject will therefore depend on more exact knowledge of the physical and chemical properties of the lubricated surface, as well as of the lubricants themselves. Work in this subject has therefore been mainly confined to a study of the frictional properties of molecular layers of lubricating substances. Wear is being studied by mechanical and metallurgical methods and more recently by means of a radio-active tracer technique.

Despite the technical importance of the mechanical properties of metals, the numerous attempts to predict these properties from general principles have met with very little success. Since metals are crystalline, the properties of the crystals define the behaviour of the metal in bulk. A better knowledge of the properties of crystals, especially of their mechanical properties and the way these may be changed by heat treatment, is therefore required. The programme of the group has this general aim in view.

The work on explosives continues to develop in a most satisfactory way, and has made substantial contributions to knowledge of the mechanism of explosion in liquids. One of the members of the explosives group is at present studying gas kinetics with Professor Hinshelwood at Oxford University. Two officers of the Section are working with the Research Group for the Study of Physics and Chemistry of Rubbing Surfaces at Cambridge. Close collaboration with this laboratory continues.

Thanks to the continued generosity of Professor Hartung, the Section is still mainly housed in the Chemistry Department of the University of Melbourne. Two temporary huts in the University grounds have taken up the overflow. The Section owes a great deal to the active co-operation and help of the University, particularly of the Chemistry, Metallurgy, Engineering and Physics Departments, which have all allowed the Section the use of many of their facilities.

2. *Lubrication, Friction and Wear.*—Our knowledge of the lubrication process is still in a very incomplete state. The nature of the force which holds the boundary film to the lubricated surface, the influence of the metal surface, and the mechanism by which the film is repaired during the sliding process are still not well understood.

The properties of the boundary film or lubricant therefore continue to be the chief preoccupation of this group of the Section, and the parallel work on wear and on the actual performance of lubricated engines and bearings must always depend for its advances on the progress of the more fundamental research.

(i) *Mechanism of Boundary Lubrication.*—The frictional behaviour of boundary lubricant films of fatty acids and metal soaps of known molecular thickness is being studied on the Bowden-Leben apparatus. With films deposited by the Langmuir-Blodgett method, it has been found that with increasing temperature, changes in friction occur at temperatures corresponding to known physical and chemical changes of the lubricant in bulk.

Various metals have been shown to require different numbers of molecular layers (from one in the case of steel to seven with platinum) to give effective boudary lubrication. These results have provided valuable information on the theory of the action of these boundary lubricants. It is proposed to continue the study of the behaviour of molecular layers of lubricant additives by the use of surface potential and electron diffraction methods.

(ii) *Silicone Lubricants.*—The low viscosity-temperature co-efficient of silicone liquids makes them peculiarly suitable as lubricants under conditions where the temperature varies widely. Unfortunately they have been found to possess poor boundary lubricating properties and they would probably therefore require additive for use under extreme pressure conditions.

Silicone films of molecular thickness, however, can be put on metal surfaces by treatment of the surface, after conditioning in a high humidity atmosphere, with the vapour of an alkyl chlorsilane. Films formed in this manner reduce the friction between metal surfaces considerably, act as excellent boundary lubricants to unusually high temperatures (200°–250° C.), and show good wear-resisting properties. Tests have been made with copper, cadmium, steel, silver and platinum surfaces, and all have shown good lubrication with silicone films. The lubrication of silver surfaces is particularly interesting, since this has not been achieved previously by the normal methods of boundary lubrication. It appears that the greater the number and size of the alkyl groups in the silane the better is the lubrication, e.g. amyl silanes have been shown to be better than the ethyl compounds and di-amyl silane better than mono-amyl silane. The preparation of such substituted silanes, however, has involved a great deal of investigational work. Cetyl silanes are now being examined.

(iii) *Lubrication of Bearings and Piston Rings.*—To be of practical value any fundamental advance in the knowledge of lubricants must be related to the actual performance of moving machinery. A test engine and a bearing testing machine have therefore been designed, on which the performance of lubricating films under normal working conditions can be examined in detail.

(*a*) *Piston ring lubrication.*—In previous reports, some account has been given of a qualitative study of piston ring lubrication by electrical resistance methods in an attempt to establish more rapid methods of investigation than the traditional wear measurements. Over the last year, work on this project has been concentrated on electrical methods of integrating the resistance trace obtained on the cathode ray screen, so that

the method may become quantitative and be directly correlated with previous wear measurement work. This project is being carried on in collaboration with the Division of Aeronautics.

(*b*) *Bearing testing.*—Previous work in the Section made use of an electrical resistance method of estimating running performance of sleeve bearings, but the results were of a purely qualitative nature. An attempt to correlate this method with the Sommerfeld variable ran into considerable experimental difficulty in the measurement of friction. Some work has now been done on the design and construction of a friction balance incorporating relatively highly stressed flexure pivots. It is anticipated that this balance will allow further experimental work to be carried out in terms of the Sommerfeld variable and also provide a means of quantitatively correlating the electrical method with it.

(iv) *Radio-active Tracers for Detection of Wear.*—Radio-active tracers have been used to measure metallic transfer and wear during lubricated and unlubricated sliding. By including a radio-active isotope in one of a pair of sliding surfaces, the amount of metallic transfer can be measured by the activity of the previously stable surface, and the distribution of transferred metal shown by a photographic method.

This technique has been particularly useful in detecting transfer between two surfaces of the same metal where chemical methods cannot be used. The nature and amount of transfer bears a definite relationship to other frictional effects. Up to the present, radio-active lead, cobalt and iron have been used, but various other metals have been ordered from America.

(v) *Wear Properties of Carbon Steels.*—Experiments have been carried out to determine the relative wear properties of various plain carbon steels and the effect of various heat treatments.

The procedure consisted of drawing a hemispherical steel slider over a flat steel plate, both slider and plate being of the same composition and in the same state of heat-treatment. The torn tracks thus produced on the surface of the plate were investigated by means of taper sectioning in which the depth of the tracks is very greatly magnified. By comparison of the tracks on all the plates used an indication of the relative wear properties of the various steels can be obtained.

The experiments are not yet complete, but it appears that a steel with about 0.7 per cent. C. after quenching and tempering, and a 1.1 per cent. C. steel after spheroidizing, show better wear resistance than the other steels investigated.

(vi) *General Lubrication Work.*—Work is being carried out on the effect of surface finish on the friction of lubricated and unlubricated metal surfaces and also on the rate of corrosion of metal surfaces in contact with oils containing fatty acids. A number of small *ad hoc* problems have been investigated at the request of various other government departments and industrial firms.

(vii) *Electrolytic Polishing.*—Electrolytic polishing has continued to be applied extensively to various research problems. It has proved very useful as a method of preparing surfaces free from deformation for frictional measurements. It has also become a routine method for the preparation of metal specimens for microscopic investigation. Metals for which the method has been applied include aluminium, cadmium, copper, lead, magnesium, silver, iron, tin and zinc and their alloys.

The experience gained in this field has been valuable in applying this new method of surface preparation to industrial processes. Among the investigations which have been carried out for industrial firms are the electrolytic polishing of pressed aluminium articles. At the request of industrial users, a comprehensive report of the method has been prepared and distributed.

3. *Metal Physics.*—The work in the field of metal physics is concerned (*a*) with plastic deformation and strength, and (*b*) with phase transformations and their mechanism.

(i) *Plastic Deformation.*—In order to explain the deformation of metals satisfactorily, the mutual interaction of the crystals and the manner in which they take part in the deformation have to be understood. It has become obvious from the results of investigations that neither the metal specimen as a whole nor the crystals comprising it deform uniformly. Three sources of this non-uniformity have been investigated.

(*a*) *Anisotropy of plastic properties.*—Crystals with different orientations of their crystallographic axes relative to the direction of the applied stress show different elastic limits and work hardening characteristics. Hence they deform to different extents if the specimen is deformed; the deformation of the specimen being an average value of the stains suffered by the crystals. Even within a grain the extent of deformation varies when one traverses from one boundary through the crystal to the other boundary, and the hardness values vary correspondingly because of the work-hardening effect. A crystal is deformed in the neighbourhood of its boundary to a smaller or larger extent than in its centre depending on whether the average deformation of the neighbour is smaller or larger. This effect of the neighbour is still observable at a distance of $\frac{1}{4}$ inch from the boundary.

(*b*) *Type of deformation.*—In drawing and rolling, the surface of the metal is in contact with the tool and is deformed differently from the centre because of the frictional forces. On annealing, the more heavily deformed part of the specimen recrystallizes at a lower temperature than the less deformed part. Experiments on brass wire have been completed. They have shown that the surface of the wire recrystallizes before the centre. The investigation is being continued with iron.

(*c*) *Presence of two phases in an alloy* (*two-phase alloys*).—The work on the deformation and recrystallization of 60-40 brass reported last year is now complete, and an account is now being prepared for publication. The soft alpha-phase is deformed at a lower stress than the beta-phase. On annealing the recrystallization of a quenched alloy starts in the alpha-phase and of a slowly cooled alloy starts in the beta-phase. The work-hardening characteristics of the alloy in the two different states are apparently different, at least in the early stages of the deformation. It is thought that the order-disorder transformation taking place in the beta-phase is responsible for this difference even though order is destroyed by extensive cold working.

(ii) *Phase Changes in Solid Metals.*—(*a*) *Diffusion.*—Diffusion is the basic mechanism by which any phase-change in the solid state occurs. In spite of its importance the details of the process are very little understood. Using radio-active isotopes of iron and cobalt the rates of self-diffusion of these elements are being determined. By measuring these rates at temperatures above and below those of the allotropic transformations, the effect of crystal structure on the heat of activation for diffusion will be examined.

(*b*) *Order-disorder transformation in beta-brass.*—Although very extensive investigations of this transformation have been carried out, it is not known whether the order can be destroyed by cold working. The brittleness of the beta-phase has obviously made impossible an extensive deformation of the alloy. By using a duplex alloy in which crystals of the beta-phase are embedded in soft crystals of the ductile alpha-phase, large deformations of the beta-phase can be obtained. Measurements of the electrical resistivity of the duplex alloy after various amounts of reduction

in area, by wire drawing, have shown that the resistivity increases as expected if the order in the beta-phase is destroyed.

4. *Explosives.*—The propagation of detonation through thin layers of liquid explosives is being studied by high-speed photographic methods.

It has been shown that from the point of initiation a relatively slow and gentle process spreads out for a short distance, until suddenly detonation is set up. Initiation of detonation occurs spontaneously ahead of the flame front of the previous gentle process, probably as a result of the combined effects of shock and heat from the reaction, and simultaneously a "retonation" wave is sent *back* through the hot gaseous products remaining in the wake of the primary flame. All these processes have their parallel in gaseous explosions, in fact the phenomena observed in the thin liquid films may be considered as almost exact replicas (in miniature) of many of the well-known effects characteristic of the setting up of the detonation wave in gaseous mixtures.

A further resemblance lies in the behaviour of hot gases—"Schwaden"—remaining in the wake of the detonation wave. These have been shown to move rapidly after the detonation wave travelling with gradually decreasing velocity in the same direction, until after a short time their motion is reversed and they travel rather more slowly in the opposite direction. The propagation of explosion in a thin liquid film has also been shown to be an essentially discontinuous process, "detonation" appearing to consist of a succession of powerful but extremely localized explosions, rapidly following one upon the other.

These results were mainly obtained in work using nitroglycerine. It has been shown, however, that other liquid explosives have the same characteristics.

At the present time events preceding the detonation wave are being examined by means of flash and Schlieren photography. Considerable progress has been made with the construction of new high-speed rotating camera, which will be used for a detailed examination of the complex propagation mechanism.

5. *General.*—(i) *Electronics.*—A small electronics group is at present engaged on the design and construction of electronic equipment for much of the research programme outlined above. It is clear that electronics is very much more than a convenient tool to be applied to various problems. Much of the work of the Section could not even have been contemplated without the co-operation and advice of the electronics staff, who, although not nominally responsible for such work, have made themselves an integral part of all the research teams.

Specifically, the electronics group has been responsible for:—(*a*) Design and construction of an integrating circuit for the test engine to correlate cylinder wear with the electrical resistance of the oil film between cylinder and piston ring; (*b*) construction of Geiger Muller Counter for radio-active tracer and diffusion work; (*c*) design and construction of an X-ray diffraction unit; (*d*) design of an electron diffraction unit; (*e*) design of electrical circuits for flash photography of detonation waves; (*f*) design and construction of electrical circuits for measurement of variations in specific heats of gases under rapid compression (since handed over to Division of Aeronautics).

(ii) *Rheological Properties of Australian Bentonites.*—The rheological, base exchange, and filtering properties of Australian bentonites are being examined to find whether they are suitable or can be made suitable for use in oil well drilling fluids. For this purpose a relatively low concentration of bentonite in water should form stable thixotropic gel suspensions with a high yield value. They should also be able to form a filter cake with a low permeability.

A Wyoming bentonite with satisfactory properties was used as a standard of comparison. The results to date show that while none of the Australian bentonites, as found, are equal to Wyoming bentonite, they can be considerably improved by treatments involving base-exchange reactions.

The work is being continued on these lines and has involved the development of techniques for measurements of base exchange, filter cake permeability, yield value, thixotropy, swelling pressure, particle size, etc.

(iii) *Mechanical Engineering Facilities.*—The Section has been fortunate in still being allowed to make use of workshop and other equipment of the University of Melbourne, despite the extreme pressure on the University facilities caused by the greatly increased number of students. At the same time, it is realized that this can only be regarded as a temporary privilege since it must disrupt University work to a certain extent. Therefore advantage was taken of an opportunity of obtaining surplus machine tools from the Directorate of Machine Tools and Gauges. It can now be said that the Section workshops are complete in so far as existing temporary accommodation will allow, and that only comparatively minor additions are required to make the Section entirely self-sufficient in this respect.

(iv) *Miscellaneous.*—The Section has continued to give assistance and advice on lubrication and bearing problems to many government departments and to a wide variety of industrial organizations. Some of the fundamental work has proved to have a direct application to the study of bearing performance and two papers on this aspect of the work have been published. Members of the Section are acting on various technical committees and in particular on the Engineering Group Committee through which it keeps in close touch with Munitions Supply Laboratories and other laboratories of the Council in Sydney and Melbourne. Recently, in conjunction with the Division of Aeronautics a series of Metallurgical Colloquia has been initiated to discuss metallurgical work in progress in the various metallurgical laboratories in Melbourne. The large attendance and lively discussion have indicated that these meetings fill a real need.

6. *Publications.*—The following papers were published during the year:—

Boas, W., and Honeycombe, R. W. K. (1946).—The plastic deformation of non-cubic metals by heating and cooling. *Proc. Roy. Soc.* A.186: 57.

Boas, W., and Honeycombe, R. W. K. (1947).—The anisotropy of thermal expansion as a cause of deformation in metals and alloys. Ibid. A.188: 427.

Boas, and Honeycombe, R. W. K. (1947).—The deformation of tin-base bearing alloys by heating and cooling. *J. Inst. Metals* 73: 433.

Bowden, F. P., Mulcahy, M. F. R., Vines, R. G., and Yoffe, A. (1947).—Detonation of liquid explosives by gentle impact. The effect of minute gas spaces. *Proc. Roy. Soc.* A.188: 291.

Bowden, F. P., Mulcahy, M. F. R., Vines, R. G., and Yoffe, A. (1947).—The period of impact, the time of initiation, and the rate of growth of the explosion of nitroglycerine. Ibid. A.188: 311.

Bowden, F. P., and Stone, M. A. (1946).—Visible hot spots on sliding surfaces. *Experimentia* 2: 5.

Bowden, F. P., and Stone, M. A. (1946).—Frictional hot spots in non-metallic solids. VI^{e} Congrès International de Mécanique Appliquée, Paris.

Bowden, F. P., Stone, M. A., and Tudor, G. K. (1947).—Hot spots on rubbing surfaces and the detonation of explosives by friction. *Proc. Roy. Soc.* A.188: 329.

Greenhill, E. B. (1946).—The lubrication of metals by compounds containing sulphur. VI^e Congrès International de Mécanique Appliquée, Paris.

Gregory, J. N. (1946).—The lubrication of metals by compounds containing chlorine. Ibid.

Gregory, J. N., and Spink, J. A. (1947).—Lubricating properties of molecular layers of stearic acid and calcium stearate on metal surfaces. *Nature* 159: 403.

Honeycombe, R. W. K. (1946).—Conditions leading to fatigue failure in sleeve bearings. Fatigue symposium at University of Melbourne.

Honeycombe, R. W. K., and Hughan, R. R. (1947).—The electrolytic polishing of copper in orthophosphoric acid. *J. Coun. Ind. Res.* (Aust.) 20: 297.

Moore, A. J. W. (1946).—Surface damage of sliding metals. VI^e Congrès International de Mécanique Appliquée, Paris.

(Moore, A. J. W.) (1946).—Surface contours of sliding metals. *Mon. Sci. News,* No. 8.

(Yoffe, A.) (1946).—The detonation of liquid explosives by impact. Ibid., No. 7.

XVIII. BUILDING MATERIALS RESEARCH.

1. *General.*—So far as it has been possible with the limited staff and facilities available, the Building Materials Research Laboratory has pressed forward with the programme of work outlined in the last report. Although conversion of the Aircraft Production Workshop building acquired at Highett to house the rudiments of the Laboratory was commenced last year, progress in this conversion and subdivision has been slow and, in consequence, work continues under extreme difficulties.

With the appointment of officers to take charge of the masonry and concrete investigations, all the senior positions within the Laboratory have now been filled, and the development of the research work in these two fields has been commenced. Repeated efforts to recruit additional staff have been most disappointing, however, and, as a result, the implementation of the work in the Laboratory has been greatly hampered.

The close liasion established with the Commonwealth Experimental Building Section of the Department of Works and Housing has been maintained and further developed throughout the year. In addition, the excellent relationships already established with other Commonwealth and State authorities and with all relevant branches of industry, with architects, engineers, builders and manufacturers, have materially extended. The laboratory's representation on the various Committees of the Standards Association of Australia dealing with building materials and equipment has been expanded, and the Officer-in-Charge, as a member of the Housing Standards Committee appointed by the Standards Association of Australia to determine policy and co-ordinate the work of the various specialist committees, is enabled to keep in constant touch with current building material problems.

At present the Officer-in-Charge is on an overseas visit to the United States of America, England, and the Continent, where he is inquiring into the organization and operation of building materials research in those countries. In addition, he is contacting many manufacturers of building materials and machinery for their fabrication and is obtaining much useful information on manufacturing processes and new materials on the overseas market.

2. *Information.*—(i) *General.*—Much valuable information on the manufacture, properties, and utilization of building materials is contained in the literature, and one of the functions of the Information Section is to locate it and disseminate it in a form suitable for the research worker, the manufacturer, and the user. Dissemination of this information is taking place in three ways at present: (*a*) replies to inquirers, both official and private, (*b*) reports, summaries of information, and bibliographies, and (*c*) abstracts of the literature for the library bulletin.

The work of the Section has been developed as far as possible along the lines indicated in the previous report, but continued shortage of staff has made it impracticable to commence the News Letter series so far. Furthermore, much of the time of the Information staff has had to be devoted to the numerous inquiries which have been received.

(ii) *Library.*—With the planning of various research programmes in the laboratories, the need for reference books on diverse subjects has been evident. During the year about 180 reference books were added to the library, making the total number approximately 500. These, with the addition during the same period of 1,600 pamphlets (including reprints and standards), copies of 400 patents, and trade catalogues from 250 firms, form a very useful library unit. In addition, the number of periodicals received by the Section has increased to about 120, and periodicals are routed from other libraries of the Council.

(iii) *General Inquiries.*—The following inquiries are typical of those dealt with during the year: the manufacture and utilization of concrete and concrete products, waterproofers for concrete and masonry construction, the utilization of earth for building, the production of clay bricks and tiles and of sand-lime bricks, the production of lime and its use in building, the thermal conductivities of building materials, and some problems in the use of metals in building. As a result of an article on adobe, rammed earth, and concrete blocks which appeared in a local paper, some 50 inquiries were received for information on these materials.

(iv) *Reports and Information Summaries.*—Because of the numerous general inquiries which have required attention, it has not been possible to devote sufficient time to the preparation of any comprehensive reports. However, data on a number of subjects have been compiled and will be produced in report form as opportunity offers.

In order to facilitate the design of equipment for carrying out accelerated weathering tests on building materials and the evaluation of the results obtainable therefrom, information on the fundamental processes of weathering was required by the testing laboratory. A literature survey on the major branches of materials weathering has now been largely completed, but it is evident that, apart from studies on paints and the corrosion of metals, relatively little information on the fundamental reasons for the break-down and change of materials on exposure to the weather has been published, a fact which complicates the comparison of natural and accelerated weathering tests. Since much of the weather testing of building materials must be carried out by artificial means to obtain results in a reasonably short time, an examination of the relationship between artificial and natural weathering agencies appears to be necessary.

(v) *Photography.*—Some photographic equipment has been obtained, and a limited photography service is being given to the laboratories.

3. *Physical and Mechanical Testing Laboratory.*—(i) *General.*—The responsibilities of the Physical and Mechanical Testing Laboratory include (*a*) service to other sections in the making of physical and mechanical tests, (*b*) co-operation with other sections in the planning and implementation of work requiring a background of applied mechanics, (*c*) development of weathering-testing technique, (*d*) advice to other sections on instrumentation, and (*e*) special investigations, e.g. performance of concrete roofing tiles.

Owing to the lack of equipment, it is not yet possible to make within the laboratory many of the tests desired, although advantage has been taken, on occasion, of the facilities offered by the Division of Forest Products.

Some time has been devoted to problems associated with the manufacture and performance of concrete roofing tiles. For the most part, the approach has been essentially practical, with the air of providing immediate technical assistance to industry, but latterly some more fundamental work has been undertaken. Attention has been given to the development of weathering testing techniques.

(ii) *Mechanical Testing and Equipment.*—(*a*) *Testing machines and mechanical testing.*—The blueprints of the 1,000,000 lb. universal testing machine, ordered last year, have been received, and the preparation of details for the construction of the machine has begun. Preliminary inquiries indicate that the machine can be constructed in Australia, but its completion and erection will probably take at least two years. A 60,000 lb. universal testing machine has been ordered and is expected in about five months time. To accommodate weaker materials, machines of 5,000 lb. and 500 lb. capacities have been designed and the latter already constructed.

Impact testing has received some consideration. The Izod values of plaster, fibrous plaster, and a number of other building boards have been briefly investigated to determine a suitable capacity for an Izod machine to be used on these materials. Their exceptionally low strength introduces difficulties, particularly as it may be desirable to test thin sheet material in single thicknesses. The limited tests made on fibrous plaster showed a high sensitivity to fibre density, and left little doubt that Izod tests could be of considerable importance. Other mechanical tests, chiefly on strength, were limited to concrete roofing tiles, concrete building units, and a few plaster specimens.

(*b*) *Presses.*—A small 10-ton hot plate laboratory press has been installed and a 150-ton hot plate press ordered for general use. The latter will be used in concrete, sand-lime bricks, ceramics, and building boards investigations.

(iii) *Physical Testing Equipment and Services.*—(*a*) *Conditioning rooms.*—No conditioning rooms are yet available, although the installation of a fog room for concrete curing and a cyclic room for weathering studies and general use will be commenced as soon as possible. The construction of an additional cyclic room and two constant temperature conditioning rooms has been planned.

(*b*) *Weathering testing.*—An "Atlas" twin-arc weatherometer, lately installed, has been used exclusively, so far, in the investigation of caulknig compounds. A further weatherometer, designed particularly for use with roofing tiles, has been constructed. Freezing-and-thawing and wetting-and-drying tests are under consideration and salt spray equipment has been ordered.

(*c*) *Moisture permeability.*—Apparatus for determining the permeability of mortars, plaster, ceramics, asbestos cement and other sheet material, under a 20-cm. head, has been developed and installed.

(*d*) *Linear expansion apparatus.*—Equipment has been constructed for determining the movement due to change in either temperature or moisture content of materials of low expansion co-efficients. This equipment has been used for *ad hoc* tests on clay bricks. A comparator for the measurement of drying shrinkage in concrete has also been constructed.

(*e*) *Abrasion testing.*—A flagstone abrasion machine, at present being used by the Surfacing Materials Section, has been installed.

(*f*) *Fire resistance of building materials.*—Methods of evaluating the fire resistance of building materials have been reviewed, but no facility for making such tests has been provided.

(*g*) *Particle size determination.*—In co-operation with the Masonry Section, an elutriator of the Kriehbel type, for the examination of the particle size distribution of cement, plaster and clay, has been designed.

(iv) *Weathering Studies.*—The question of developing weathering techniques has been considered in detail. Although it is desirable to develop the well-known "weatherometry", "freezing-and-thawing" and "wetting-and-drying" tests, it is intended to obtain basic information on which to establish accelerated and other laboratory weathering techniques. This will be done by approaching the subject of weathering from a more fundamental aspect, i.e. the examination of the conditions of radiation moisture, &c., to which materials are subjected in service. Determination of the duration and quantitative spectral distribution of solar radiation in selected localities is planned as a starting point. Concurrently, correlation of these factors with the corresponding "sol-air" and black-body temperatures and with general meteorological data is intended.

On several occasions during the year, the problem of water-proofness and weather resistance of mortars, in the form of tiles and wall sheathing or renderings, has arisen. Consideration has been given to the development of apparatus for investigating the bearing on these properties of such factors as particle size and grading of the aggregate, water/cement ratio, void or capillary dimensions, physical characteristics of aggregates, and richness of mix, with the ultimate aim of determining the mode and rate of moisture transfer. Similar investigations on plaster are contemplated.

(v) *Concrete Roofing Tiles.*—Attention has been devoted to the problems associated with portland cement concrete roofing tiles, with the object of directly assisting the expansion of this industry and the improvement of the quality of its product. After examining industrial practice, a report on production methods was prepared and circulated to manufacturers and public authorities throughout Australia. Numerous technical inquiries on this subject have also been answered. Such factors as grading of sand, moisture permeability, and colour have been investigated experimentally, and information collected on overseas methods.

The outstanding problem in the concrete tile industry is the production of a weather-resistant surface finish. Work is now proceeding on the development of a water-proof, smooth surface free from fading and efflorescence. At the same time, it is hoped that the production of a glaze will be achieved and that its smoothness will prevent the adherence of wind-borne material with a consequent reduction in the incidence of vegetation. Already an improved trowelled surface has been produced, but the widely-used spraying method introduces additional rheological problems which are now receiving attention.

4. *Concrete Investigations.*—Although much time has been given to technical inquiries and the design and construction of equipment, the main investigational work has been connected with the methods of

manufacture and the properties of light-weight concrete. This project can be considered as embracing four lines of attack—(*a*) Investigations concerned with materials. Apart from cement, the main components are aggregates, aerating agents, and surface-active agents. (*b*) Investigations concerned with the design of mixes and methods of fabrication. (*c*) Investigations concerned with the curing of light-weight concrete. The use of vacuum treatment and methods of autoclave curing and electro-curing are included in this work. (*d*) Examination of the properties of experimental products. In addition to physical properties, such as volume change under various conditions, density/strength relationships, absorption and conductivity, attention is being given to the general question of durability under service conditions.

This work, which has necessarily been of an empirical nature in its early stages, has consisted of a long series of trials and tests involving variations in such factors as the nature and quantity of the aerating agent, the nature and quantity of the surface-active agent, the nature and quantity of the aggregate, the method of mixing, and the time of curing. For dependable and enduring work, however, this project must be treated as a long-term one. Very little is really known about the effect of surface-active agents on cement and concrete, and consequently there is a wide field here for fundamental investigation.

5. *Masonry Investigations.*—With the appointment of the Officer-in-charge of Masonry Investigations in January last, together with that of a second officer with a wide overseas research and practical experience in ceramic and masonry products, consideration has now been given to the development of a programme of research on materials which may be considered under the general heading of masonry.

From an over-all survey of the problems considered initially by the Building Materials Research Advisory Committee, of those presented by the Commonwealth Experimental Building Station of the Department of Works and Housing as complementary to its investigations, and of those submitted by the various housing authorities and private interests, it has been clearly demonstrated that the following projects should receive attention:—(i) Fundamental research into the raw materials, i.e. sand, clay and lime, used in the manufacture of masonry units. (ii) Production and properties of clay bricks and tiles. (iii) Production and properties of sand-lime bricks. (iv) Composition and properties of lime mortars. (v) Production and properties of concrete blocks. (vi) Properties of natural building stones. (vii) Properties of soils used as building materials and foundations. (viii) Physical and mechanical characteristics, strength, permeability, &c., of bonded masonry units.

An initial survey of these problems has indicated that much fundamental work is required on the nature and composition of all Australian raw materials used either directly as, or in the manufacture of, masonry units. There is little uniformity in the quality of the manufactured products, and there is, in consequence, a demand for research work to improve quality; this is true of common clay bricks and tiles, and is particularly so in the case of concrete blocks and tiles. Shrinkage, cracking, and mechanical failure in masonry structures are common faults, and the investigation of the properties and setting of mortars and the bonding of masonry units is urgently needed.

To initiate and develop every one of the projects listed above would involve a large team of workers; hence it has been decided that the Masonry Section must, for the time being, concentrate its activities on two groups only of these projects, viz. heavy-clay products, i.e. bricks and tiles, and sand-lime products, including sand-lime bricks and lime mortars. Fundamental research into the three raw materials, sands, lime and clays, will form an integral part of the work of the projects.

So far as concrete bricks and blocks are concerned, preliminary work, as it relates to composition and properties, falls within the scope of the Concrete Section. Similarly, work on the physical and mechanical properties of bonded masonry units falls within the scope of the Physical and Mechanical Testing Laboratory. The Division of Soils has already established a programme of research on soils from the foundation point of view, and, consequently, it is unnecessary for the Masonry Section to undertake any direct work in this field at present.

It is not intended to develop an extended programme of work at present on natural building stones, although it will be necessary, in view of the importance of these stones in South Australia, to pay some immediate attention to them, particularly as regards the development of a method for assessing weatherability.

6. *Surfacing Materials.*—(i) *General.*—During the past twelve months the Section has been engaged on three main projects, namely, the study of floor surfaces with special regard to those based on concrete, the development of suitable surfacing material for bathrooms and kitchen walls, and the study of gypsum plasters.

With the exception of the lastnamed, for which there is in existence an extensive scientific and technical literature, a conspicuous feature of these projects has been the almost complete absence of reliable factual information concerning the materials at present being used. Such published statement as are available consist, with minor exceptions, of those made or inspired by manufacturers of proprietary products, the compositions of which are, more often than not, unknown. It has, therefore, become necessary, in order to provide background information for the planning of more detailed fundamental studies, to make a survey of materials at present being used for such purposes, and to endeavour to determine in the laboratory their composition and the extent to which they fulfil the claims made for them.

(ii) *Floor Surfaces.*—This problem resolves itself naturally into two main parts, the physiological effect of the floor surface on those who walk and stand on it (i.e. the comfort of the floor), and the physical effects of the walker on the floor surface (i.e. the durability of the floor).

(*a*) *Comfort.*—The former part of the problem is immediately susceptible to a fundamental bio-physical approach, since it is almost certain that the subjective phenomenon of comfort as applied to a floor can be resolved into mechanical and/or thermal effects on the feet. Although the distribution of pressure on the soles of the human feet has long been of interest to physiologists, little progress has been made in the measurement of such pressure distribution except for the barefooted subject standing or walking on specially prepared surfaces. For the present purpose, however, it is desirable to measure, if possible, both the time and space distributions of pressure when a man or woman with shod feet walks on a variety of floor surfaces.

Since a complete pace lasts only about half a second, the duration of pressure on any one portion of the foot is so short that most ordinary methods of pressure recording cannot be applied. An electronic pressure gauge which will respond with sufficient speed to enable transient pressures of such duration to be recorded with ease, and which can be readily fitted into an ordinary shoe without discomfort to the wearer, has now been developed. So far, it has not been found possible to make these pressure gauges respond satisfactorily to loads corresponding to more than about a quarter of the body weight of an average man. Work is now proceeding on the design of these gauges with a view to improving their response at higher pressures.

(*b*) *Durability.*—(1) *Abrasion resistance of concrete floors.*—Apart from actual usage trials, which are necessarily lengthy and are often difficult to evaluate because of the effects of uncontrollable variables, the normal method of comparing the durability of floor surfacing materials is by means of some type of abrasion machine. Many such machines operating on various principles have been described in the technical literature, and some are available commercially. None of them duplicate exactly the wear occurring under normal traffic, and the results obtained with different machines vary considerably.

As a prelude to a study of the types of wear produced by the different varieties of abrasion machines, by various types of traffic on pavements, as well as the effect on wear-resistance of variation in type and quantity of the ingredients used for the floors, an examination of the rumbler-type machine specified in British Standard 368: 1936 for the testing of precast concrete flagstones has been commenced. The behaviour of a series of concrete flooring mixtures with and without special aggregates and hardening solutions is at present being examined in this machine. Preliminary results indicate that it may be possible, by a modification in the design of the machine, to accelerate the test (which at present requires 48 hours) considerably without appreciably altering the type of wear.

It is proposed eventually to obtain abrasion machines of other types and to examine the type of wear produced in each for correlation with the wear found in practical use.

(2) *Mastic flooring.*—Samples of English pitch mastic which had been proposed for use as surfacing for concrete-floored domestic buildings have been examined and found to flow under loads of approximately 2½ lb. per square inch at room temperature, indicating that serious marking could be expected by quite light articles of furniture.

Test floors of various types of cold-laid bituminous mastics have been installed over concrete sub-floors in several laboratories and workshops, and their behaviour under traffic is being observed continuously. Staff using these rooms report a marked improvement in comfort over the original concrete surfaces.

(iii) *Bathroom and Kitchen Wall Surfaces.*—In this field, even more than in the work on floor surfaces, is the absence of previous published data felt. A literature search has revealed nothing bearing directly on the problem of the soap resistance of wall surfacing materials, and consequently a survey of the behaviour of available materials is most essential to provide a starting point for more detailed and fundamental studies.

A testing chamber in which suitable panels can be subjected to a cyclic test simulating the treatment received by the walls of a shower cabinet has been constructed. As soon as the necessary automatic control gear is available, it will be used to test, for durability under these conditions, representative samples of the types of material at present employed and proposed to be employed for the walls of bathrooms and shower cabinets. From the data so obtained, a selection will be made of the types of material which could profitably be studied in greater detail.

Some preliminary work has been carried out under static conditions with regard to the soap and heat resistance of lacquer and enamel paint types of coating. It was found that while nitrocellulose lacquers will resist the action of soap very much better than synthetic enamels of the alkyd type, they are rather less resistant to heat.

(iv) *Gypsum Plaster.*—All known manufacturers of plaster in New South Wales, Victoria, South Australia, and Western Australia, as well as many of the users, have been contacted in order to determine the problems of the plaster industry in Australia.

A start has also been made on a critical survey of the voluminous technical literature on this subject. When completed, it will serve as a basis for fundamental experimental work on the chemical and physico-chemical properties of gypsum and gypsum plasters.

In connexion with the problems of gypsum slab-wall houses, such as are being erected in South Australia and are proposed to be erected in Victoria, experiments have been commenced on the problem of decreasing the water-absorption of plaster slabs, and an instrument has been devised which promises to be useful for the measurement of the adhesion of renderings to such walls.

7. *Building Boards and Insulating Materials.*—(i) *General.*—It was recorded in the previous report, following a perusal of literature and an examination of some of the requirements of the industry, that the broad outline of the investigation on building boards and insulating materials had been conceived and that preparatory work was starting. Since that time, the laboratory working space has been organized, many items of equipment obtained or ordered, and designs produced for a number of pieces of special apparatus which are not available on the market. In addition, the Section provides the facilities for the design and construction of such electronic measuring devices as may be required by the laboratory as a whole.

(ii) *Building Boards.*—The properties of these boards which have engaged most attention are those of strength and the changes of dimensions caused by variations in atmospheric conditions. The most important observation so far obtained is that the energy required for breaking a building board specimen is the best available criterion for measuring its suitability as regards strength. A small testing machine for flexual testing (loads up to 30 lb.) has been completed, and a machine of the universal type (maximum load 5,000 lb.) is under construction. Two cabinets with double-glazed doors have been built to permit measurements without removal of the specimens. The temperature and humidity conditions within the cabinets can be varied as required.

A search for a suitable fibre of Australian origin for use in fibrous plaster has been undertaken. Scrim hessian, flax tow, and "Soylux" fibre (produced in New South Wales) have been proposed, but it has been demonstrated that none of these is suitable. Fibre from a cactus (claimed to be *Agave rigida vivapara*) growing in semi-wild condition in Western Australia has been shown to be suitable. A number of other fibres are being investigated.

(iii) *Thermal Conductivity.*—The following standard types of apparatus are being constructed for measuring the thermal conductivity of building materials:—(*a*) A guarded hot plate apparatus to accommodate a 12-in. by 12-in. specimen (up to 1½-in. thick). This is at present being constructed in the workshops of the Division of Physics. (*b*) A guarded hot plate apparatus to accommodate a 48-in. by 48-in. specimen will be constructed in the workshops at Highett. (*c*) A guarded hot box apparatus capable of taking specimens about six feet square. As it will be some time before these are completed, a temporary guarded hot plate apparatus has been set up in the laboratory to obtain approximate results and operating experience, and a modified hot box has been made with which rapid results may be obtained.

Methods are being investigated for simultaneously measuring thermal conductivity and specific heat, but, up to the present, work in this connexion has mainly been concerned with the mathematical evaluation of expected conditions and results.

(iv) *Acoustics.*—Owing to the difficulty of obtaining adequately trained staff, it has not been possible to press forward with the work on acoustics. However,

some equipment has been placed on order and is expected to be available by the time an attack on this problem can be undertaken.

(v) *Electronics.*—The Section has produced small pieces of measuring equipment for other sections and progress has been made in the design of other apparatus of this type.

8. *Organic Materials Investigations.*—(i) *General.*—The construction of the Organic Laboratory, which was commenced towards the close of the previous financial year was completed in December, 1946. Research work on the properties of building mastics was commenced early in the year, and several incidental investigations of problems of immediate interest to the building industry have been made.

(ii) *Building Mastics (Caulking Compounds and Putties).*—As previously reported, material for the study of the properties of caulking compounds has been collected and represents, so far as is known, all the proprietary caulking products at present marketed in Australia. These are now being systematically studied to determine performance under various installation conditions. Each of the compounds received is currently undergoing tests in grooved masonry blocks exposed to the weather at Highett. Plans have been made to extend these tests to other climatic conditions. With the co-operation of the Victorian Housing Commission, it has also been possible to initiate a limited number of tests under service conditions in the joints of several "V.H.C." pre-cast concrete houses.

Exposure of a number of the mastics to artificial weathering (in an "Atlas" twin-arc weatherometer) with continuous light and a three-minute water spray cycle in each twenty minutes has also been undertaken in order to determine whether accelerated testing has any practical value for evaluation of these products.

Precise conclusions cannot yet be drawn from the tests performed to date, but it may be stated that a number of the materials examined exhibited serious deterioration of adhesive and plastic properties after a relatively short period (approximately two months) of weathering. Such compounds can at best have only limited use, but further work is necessary to determine their value under less rigorous conditions.

Concurrently with the foregoing, the materials are being investigated in the laboratory for their evaluation, and to determine the relationship of their properties with the requirements of current foreign standard specifications. As a prelude to the specification testing, it was necessary to select a suitable standard porous masonry material. Sydney sandstone from the Wondabyne quarry of the Hawkesbury Sandstone Company was finally selected on the basis of its availability and its uniformity as regards porosity.

It is realized, of course, that foreign specifications may not be entirely suitable for local conditions, and the evaluation of existing laboratory tests is as much an object of this work as the evaluation of the caulking compounds themselves. The value of any laboratory tests will, of course, be checked by comparison with performance under service conditions.

Consideration has also been given to the question of suitable techniques for the measurement of the fundamental rheological properties of mastic materials. For research purposes, the various empirical devices, commonly used to determine "plasticity values", etc., are considered inadequate, and attention has been given to the determination of the equations of flow for these materials. Experimental work to date has related to the shearing effect of thin plates embedded in putties.

As a result of contacts established with officers of the Victorian Housing Commission in relation to the caulking of wall joints in the "V.H.C." concrete house, a pneumatically-operated caulking gun has been devised which permits caulking operations, using standard knifing-grade material, to be effected with increased efficiency and economy. This equipment is being adopted by the Commission for use in the concrete house project. A full description of the apparatus has been published in the Council's *Journal.*

During the year a request was received from the Victorian Housing Commission for assistance in the specification of suitable steel-sash glazing putties. The problem has been investigated in the light of the many points of similarity between these materials and plastic caulking compounds. At the time of writing the work is not complete, but a number of tests have been devised which are believed to differentiate between satisfactory and unsatisfactory materials.

(iii) *Protection of Mirror Films from Moisture.*—Following a request by the Panel of Architects, Victorian Housing Commission, a number of cases of deterioration of the silver films of mirrors fitted in bathrooms in Commission houses were investigated. As a result, it was concluded that the damage was due to ingress of moisture, and that poor-quality mirror backing paint and poor silvering technique were contributory causes. With the co-operation of the General Chemistry Section, Munitions Supply Laboratories, Maribyrnong, work was undertaken to determine the most effective protective coating for the silver film and the relation of silvering technique to durability of the film. A final report is not yet available from the Munitions Supply Laboratories, but it has been found that silver films deposited by the Braschear process, and protected with a good-quality bitumen paint, are reasonably impervious to attack by moisture. Attempts are now to be made to correlate these observations with data on film thicknesses and moisture-impermeability measurements of the paint film.

(iv) *Adhesives for Papering Concrete Walls.*—Contacts with both public and private authorities concerned with pre-cast concrete house construction indicated that some information was required on decorative treatments for the walls of concrete houses. The usual plastering technique occasionally gives difficulties in these systems on account of the smoothness of the form side of the concrete slab, and, while papering was considered a possible alternative, some doubts were entertained regarding the efficacy of the usual paper-hanging adhesives for this type of wall surface.

Accordingly, a series of test specimens was prepared in which a variety of concrete surfaces were prepared, using three different types of commercially available adhesives, viz. casein (low alkali content), animal glue, and starch paste. Allowances was made for such variables as weight and texture of paper and backing paper, and sizing technique. The specimens were stored indoors in the laboratory buildings. Insufficient time has elapsed to determine whether any of the specimens are unsatisfactory. To date, all appear quite satisfactory, although the animal glue was considered to be less tractable than the others and caused staining of the paper.

(v) *Instrumentation.*—Some time has been spent in devising and constructing specialized items of equipment for use in studying the properties of mastics. An electrical device has been developed to eliminate personal errors in the manual operation of a standard penetrometer. This consists of a solenoid attachment, which is actuated by a time-delay circuit incorporating a thyratron valve and post-office relay. It has been found possible by this means to control a five-second penetration period with an accuracy of 0.02 second. Another time-indicating device consisting of a relay and condenser-discharge circuit has been devised to permit rapid periodic readings of rate of shear of

caulking compounds and putties. A constant rate-of-strain tensile testing machine and a thermally operated "expanding joint" are at present under construction. The latter instrument is intended to reproduce the repeated small dimensional changes which may be encountered by mastics in joints subject to expansive and contractive movement.

(vi) *Bituminous Materials.*—It was hoped during the year that it might be possible to commence experimental work on the properties of bituminous roofing materials. A study of the properties of natural and residual bituminous building materials was originally recommended by the Building Materials Research Advisory Committee, and there is a widespread need at present for reliable information on the performance of bituminous roll roofing. An appreciation was made, therefore, of the various aspects of this problem which required attention and steps were taken to appoint an officer to undertake the investigation. Unfortunately, however, this vacancy has not as yet been filled and the matter is at present in abeyance.

(vii) *Paints.*—Throughout the year a liaison has been maintained between paint users and the paint testing laboratory, Munitions Supply Laboratories, Maribyrnong. The Officer-in-Charge of the Organic Materials Section represents the Council on the Paint and Varnish Committees of the Standards Association of Australia.

9. *Publication.*—During the year a paper was given on trends in the development, and uses of building materials, a mimeographed report on concrete tile production was issued, and the following paper was published:—

Holmes, B. M. (1947).—A pneumatically operated caulking gun. *J. Coun. Sci. Ind. Res.* (Aust.) 20: 306-10.

XIX. FLAX RESEARCH.

1. *General.*—The building alterations which were initiated some fifteen months ago, when it was decided to provide temporary accommodation for the Flax Research Laboratory in the former Department of Aircraft Production workshop at Highett, have not yet been completed. This means that, apart from retting investigations and routine straw evaluations, the work of the Section is still being carried on in the very limited accommodation available at the Division of Forest Products. An early improvement in this state of affairs is anticipated, however, and should result in the more efficient working of the Section.

During the period under review, the Officer-in-Charge of the Section, together with the Chairman of the Flax Production Committee, Department of Supply and Shipping, visited various flax organizations in England, Ireland, France, Belgium, and Holland. Visits to Canada and the United States were made later by the Officer-in-Charge before his return to Australia. These visits proved of considerable value in that they enabled contacts to be made with flax research workers overseas and provided an opportunity to obtain first-hand information about the industry in these countries. While in Belfast, arrangements were made for the purchase by the Council of an experimental flax spinning plant, which it is hoped will be in operation early in 1948.

In order to ensure that the necessarily limited staff and equipment of the Section will be used in the best interests of the industry, the Flax Research Advisory Committee, which consists of representatives of the growers, spinners, and the Flax Production Committee, assists by advising as to the relative importance of the many problems awaiting solution. Close liaison is maintained with the Waite Agricultural Research Institute and the Agricultural Departments of Victoria, South Australia, Western Australia, and Tasmania on the agricultural aspect of the work, and with the Flax Production Committee on the commercial side of the industry.

2. *Agricultural.*—(i) *Survey of Factors Influencing Fibre Quality.*—This project, which was begun last year, has already proved of considerable value, not only in indicating the effect of fibre quality of various agricultural factors, but also in providing data on which to plan new investigations. For example, special manurial trials are being made this year by the Victorian Department of Agriculture as a result of recommendations based on data collected in this survey.

The survey covers at least ten growers in each of six flax-growing districts in Victoria, and includes the history of the field in which the flax is grown, sowing, growing, harvesting, and crop details, and the chemical analyses of the soil and plants. A number of the 1946 crops have now been processed and the fibre graded, but some time must elapse before the information is complete and the actual work of statistically correlating the results can be undertaken. In the meantime, a similar survey of the 1947 crops has been commenced.

(ii) *Flax Seed Investigations.*—The microscopic examination of locally grown flax sowing seed for mechanical damage has been completed on a large number of samples from the 1946 crops. Damage, in the form of cracks in the seed coat, which was fairly severe in 1945, has been much less severe this year, probably as the result of closer attention to the adjustment of the breaking rollers in the seed cleaning equipment. Deseeding by dual harvesting, however, resulted in over 50 per cent. damaged seeds as compared with an average of approximately 4 per cent. in seed from mill-deseeded straw.

Methods of determining the moisture content and oil content of flax seed have been investigated in an endeavour to remove some of the discrepancies observed from time to time when different techniques have been employed. Standard procedures have now been established.

(iii) *Processing and Fibre Evaluation of Field Trials.*—The work of processing the straw and evaluating the fibre from the field trials of the Departments of Agriculture of Victoria, South Australia, Western Australia and Tasmania and the Waite Institute, which has been carried on for a considerable number of years, has now almost been completed for the 1946 crops. These have included variety, time of sowing, rate of sowing, fertilizer and pickling trials. One pleasing feature of the variety trials this year has been the good showing of Wada, a selection made by the Western Australian Department of Agriculture, which so far has proved immune to rust and compares very favorably with other fibre varieties from the point of view of yield and quality of fibre.

More recently the work has been extended to include the general supervision of the processing of the straw from the large-scale field trials being conducted by the Flax Production Committee on varieties, rate of seeding and time of harvesting.

3. *Processing.*—(i) *Water Retting.*—Detailed studies have been made during the past seven or eight years of the part played by various factors such as temperature and dilution in water retting. This information has been published as a bulletin. Largely as a result of this work it has been possible to establish a sound but simple water retting procedure, which can be used with confidence.

The retting of Australian flax straw presents unusual difficulties in that retting appears to cease before a sufficient breakdown of the fibre-cementing material has occurred. Some simple means of obtaining a greater degree of ret in a reasonable time is being

sought. The most promising line of investigation pursued so far, is to control the pH of the retting liquor, either by aeration or chemical means. Both laboratory and mill experiments are being made.

Miscellaneous retting experiments made at the request of the Flax Production Committee have been to determine the effect on retting of the presence in the straw of a weed known as "loosestrife", of the use of various weed-killers during the growing of the flax, and of the use of "rot-proofed" binder-twine for tying the flax sheaves. Other work has been to determine means of accelerating the retting of some particularly difficult straw from one of the flax mills.

At the same time as these retting experiments are being made, the fundamental aspect of the work is receiving attention by a study of the bacteria involved. Already a considerable background of knowledge has been built up to enable a more logical approach to be made to all water retting problems. It has been shown that, although aerobic bacteria play no part in the retting process itself, they bring about the fermentation of certain flax constituents and pave the way for the subsequent development of the true retting bacteria. Methods of isolation and purification of the anaerobic retting bacteria have been developed, and at present a study is being made of the bacterial flora of Australian and overseas flax straw.

Investigations incidental to tank retting are concerned with the periodic checking of the chemical composition of the water being used at the mills for this purpose and with effluent disposal problems. The use of iron in the tanks, a practice which has been shown to assist retting, unfortunately aggravates the problem of effluent disposal on account of the black staining it produces. In some districts the iron also appears to stimulate a sulphate-reducing bacterium and results in the production of hydrogen sulphide in considerable quantities. From more detailed investigations of this action it is hoped to suggest a means of overcoming the nuisance.

(ii) *Straw Treatments before and after Retting.*—A study has been made of the effect of exposing flax straw to sunlight for various periods before retting and also of the effect of storage under cover. Exposure, except when unduly prolonged, had no effect, but storage was advantageous as regards both retting and fibre quality.

Preliminary tests have also been completed of the effect of spreading flax straw for weathering after retting. An improvement in fibre quality was obtained, but the results need confirmation on a larger scale before any definite conclusions can be drawn.

Laboratory tests on rolling wet flax straw have confirmed overseas claims that this procedure not only facilitates the drying of the straw, but also improves the quality of fibre which would otherwise tend to be harsh. Rollers have now been installed at one of the mills, and large-scale tests are in hand to obtain more information on the practicability of rolling as a routine operation.

(iii) *Flax Machinery Investigations.*—This work is carried out in co-operation with the Flax Production Committee, in that the machine shop staff and facilities at the laboratory are made available from time to time for developmental work on flax processing machinery. During the last twelve months, the work has included modifications to the butter on the pick-up binder, the construction of a set of rotor combs for testing on a scrutcher, the manufacture and assembly of equipment for making air resistance measurements on flax straw, and the construction of an experimental humidifier unit for flax straw for scrutching.

4. *Evaluation.*—(i) *Chemical Investigations.*—This work, which aims at a complete understanding of the chemical aspects of flax development and processing, is considered to be essential for an intelligent approach to many of the problems of the industry. Both Australian and high-grade overseas straw and fibre are used in most of the investigations so that a comparison can be made; where differences are detected the effect of such differences is determined and if possible the cause ascertained.

During the past twelve months the more important chemical investigations have been the study of mineral and ash constituents of straw and fibre, the relation of the chemical composition of flax fibre to its quality, the study of the properties of flax fibre cellulose, and tests of the composition of flax wax.

(ii) *Physical Investigations.*—The physical properties regularly included in the evaluation of fibre samples include tensile strength, fineness of hackled fibre, and the more important microscopic characteristics. A detailed fundamental study is now being made of the mechanical and physical properties of ultimate fibres of both Australian and overseas flaxes, and it is hoped to relate these to yarn characteristics.

Further microscopic studies have also been made of the cell structure of straw and of the progressive disintegration during retting.

5. *Publication.*—The following paper was published during the year:—

Greenhill, W. L., and Couchman, Jean F. (1947).—The water retting of flax. Résumé of investigations from 1940 to 1945. Coun. Sci. Ind. Res. (Aust.), Bull. 211.

XX. OTHER INVESTIGATIONS.

1. *Dairy Research.*—(i) *General.*—The major activity of the Section over this period has been directed to several problems of immediate importance in the manufacture of Australian butter, but it has also been possible to devote some time to, and to make considerable progress in, experiments on the better utilization of milk solids-not-fat. Staff has not been available for the more fundamental work on the physical chemistry of dairy products, nor for the study of certain engineering aspects of dairy precesses which the Section hopes to undertake.

During the year the small Dairy Section of the Division of Industrial Chemistry, which has been working as a joint team with the Dairy Research Section, was officially transferred to it, bringing the number of research officers to five.

(ii) *The Manufacture of Butter without Washing.*—The economic gain to be derived from elimination of the washing of buttermilk from the butter granules, a step in butter manufacture normally regarded as essential, was dealt with in last year's report. The experimental work up to that time indicated that while the initial grades of butters from the same cream made with and without washing were essentially the same, some of the unwashed butters deteriorated a little more rapidly in cold storage. With the co-operation of five Victorian butter factories and of the Department of Commerce and Agriculture, another experiment involving the preparation of 200 carefully controlled churnings was undertaken this year. Besides seeking confirmation of the earlier results, this experiment was designed to study the keeping quality of the butters at room temperature as well as in cold storage and to give some definition of the conditions under which omission of washing results in more rapid deterioration. To do this an extensive study of the bacteriological and chemical characteristics of the butters has been undertaken. Should last year's findings be confirmed these chemical studies, which include measurement of heavy metal contamination, serum pH, and the extent of fat oxidation occurring during storage, may indicate the nature of any additional deterioration which occurs when the butter is not washed. From what is known

of the chemical changes occurring in cold-stored butter, it would not be expected that the higher serum solids content of the unwashed butter would of itself cause more rapid deterioration. This matter is also of importance in relation to several of the new butter-making processes which give butter with high serum solids content. The experiment, which is not yet complete, is therefore expected to shed some lihgt on several aspects of butter deterioration as well as on the practical problem of whether washing of the butter granules can safely be omitted in normal manufacture.

(iii) *Weed Taint in Butter.*—The unpleasant flavours caused in cream and butter by dairy stock eating certain weeds in the pastures provide a serious problem in butter manufacture in many of our northern districts. In some of these areas maintenance of a good pasture cover throughout the year is difficult and, particularly in the winter and spring months, weeds make rapid growth. The taints derived from some of these weeds are intensified rather than removed by the processes which the cream undergoes during manufacture into butter.

Investigation of the problem was commenced last year in Queensland, with the co-operation of the Queensland Agricultural College at Lawes, the Queensland Department of Agriculture and Stock, and the Queensland Butter Board. In spite of the abnormally dry conditions which greatly reduced weed growth, some useful information was obtained. It was established definitely that much of the weed-taint in Queensland butters is of the type caused by *Coronopus didymus* or lesser swine cress. The plant causes similar trouble in New Zealand and has been the subject of study by the Dairy Research Institute there for several years. Experiments in which the weed was hand-fed to milking cows confirmed New Zealand findings as to its extreme tainting capacity, and the period which must pass after ingestion before the milk returns to normal. In New Zealand there is hope that suitable agricultural measures may be adopted to reduce the growth of *Coronopus didymus,* but there is no possibility of this at present in many of the dairying districts which are affected in Australia. Work has therefore been directed towards possible treatments of weed-taint cream to reduce or eliminate the taint. While a fundamental attack on this problem by isolation and chemical study of the flavouring substance has not yet been undertaken, it has been shown that the intensification of the taint which takes place when cream is pasteurized at high temperatures is due to a reducing action, probably by sulphhydryl groups formed from the protein. Oxidizing agents tend to reverse this change. Experiments are therefore being made with mild oxidizing treatments of the cream, but severe restriction is imposed by the necessity, under health laws, of avoiding addition of chemicals, and by the need to avoid oxidation of the fat, or conditions likely to lead to it.

C. didymus is a rather ephemeral weed and continuous study would involve its cultivation in suitable plots. This was attempted, but seeds obtained from several sources failed to germinate. It was finally found possible to germinate the seed after dissecting it from the seed coat. Experiments have also been made in the direct transfer of the taint from the weed to milk, a technique which if it can be successfully developed will simplify much experimental work.

As well as these detailed studies of *C. didymus,* a broad survey of other tainting weeds is being carried out with the assistance of the Departments of Agriculture in all States. Specimens of weeds suspected of causing taint are submitted for identification by the dairy-field officers. The tainting capacity of several suspected weeds has already been tested in feeding trials.

(iv) *The Utilization of Skim Milk Solids.*—The better utilization of the valuable solids-not-fat of milk, at present mainly used by the Australian dairy industry as a feed for stock, depends largely on drying the skim milk so that it can be readily stored, transported, and used as an ingredient in human foods. The industry has hesitated to install the expensive plant necessary for drying the skim milk because of the lack of a reliable and sufficient demand. This difficulty could be overcome if the practice of adding skim milk power to bread, which has been adopted so successfully in the United States, could be established in Australia. Early attempts by the baking industry to incorporate skim milk solids in Australian bread gave a loaf of small volume and with other quality defects. The investigation undertaken by this Section, with the assistance of the William Angliss Food Trades School, was intended to determine the factors responsible for these quality defects, so that they might be eliminated. Early experiments dealt with the quality of the dried milk, particularly the inclusion of a sufficient heat treatment in its manufacture, but little improvement was apparent in the bread. Increased lactic acid content in the milk was found to give some improvement. Skim milk powders from the United States, known to give results in bread there, were then tried and found to have the same depressing effect on bread quality as the Australian powders. Further study led to the finding that the difference in behaviour of American and Australian breads was not due to differences in the flour, but to the fact that in American bread a small percentage of fat, usually lard, is a standard ingredient. When fat was added to the dough in preparing Australian bread with milk powder, very satisfactory results were obtained. Even better results were obtained when the fat was emulsified in the skim milk before drying. Beef and mutton fats were very effective, with lard perhaps a little better. The fat plus skim milk loaves showed improvement in every physical quality in addition to the known improvement in nutritive value. Commercial scale tests have confirmed that at least 12 per cent. of skim milk powder containing 20 per cent. of emulsified fat can be added to bread. The major technical difficulty in the addition of skim milk solids to Australian bread has thus been overcome. Many minor problems remain in relation to details of baking practice, fermentation time, and the effect of various flours.

Attention is being given to the physical chemistry of the ameliorating effect of a dispersed fat phase when skim milk powder is added to bread. Present fundamental knowledge of the structure of bread and of the changes which take place in the dough does not provide an explanation of this effect.

Inventive research has been undertaken in the field of new skim milk foods, including carbonated drinks, spreads for bread, and potato and skim milk wafers. It has also been found that up to 20 per cent. of skim milk powder may be readily incorporated in sausages and other prepared meat goods with improvement in quality.

(v) *Thickening of Unsweetened Condensed Milk.*—The Navy Department has experienced trouble with thickening and acidity in some lots of Australian unsweetened condensed milk when stored in tropical climates. At its request an investigation has been undertaken. Incubation tests have confirmed the tendency to increased viscosity, lower pH, and higher titratable acidity in milk of the brand known to cause trouble. This milk has also shown a markedly higher initial viscosity. Preparations have been made for further investigation.

(vi) *DDT in Dairy Products.*—With the development in the United States of America of methods for the determination of DDT in dairy products, it has

become clear that when this insecticide is assimilated by the cow it becomes concentrated in the milk fat, and this has caused concern to health authorities in the United States. In some dairying districts in Queensland the milking cows are sprayed with DDT to control buffalo fly. Diminution of DDT concentration on the coats of the sprayed cows has been observed to take place mainly by licking. After discussion with the Division of Economic Entomology it was decided to analyse for DDT the butter from certain parts of Queensland, preferably during the early summer when the fly is most prevalent. The Division of Animal Health and Production has been treating cows for considerable periods with DDT and the milk from these will also be examined. Preparations for the analytical work have been completed.

(vii) *Australian Butter Survey.*—In 1940 the Technical Sub-Committee on Dairy Produce of the Australian Committee of Animal Production organized a survey of the properties, conditions of production, and methods of manufacture of Australian butters. Much of the survey, including the analytical determinations, was carried out by the State Departments of Agriculture, but this Section was responsible for the co-ordination of the work and for assembling the results. Concentration on urgent war-time problems had prevented publication of the data, which is extensive and of considerable value to the industry. Much time has been devoted to arranging the material in a form suitable for publication, particular attention being given to the variation in fat constants with conditions of production.

(viii) *Filter Cloths in Lactose Manufacture.*—An early step in the manufacture of lactose from whey is the coagulation of the albumen and its removal by filtration. The albumen is dried, ground, and sold as poultry food. The heavy filter cloths which are practically unobtainable soon become clogged with albumen and calcium phosphates and after a few washings cannot again be restored to a usable condition. Experiments with combined acid and enzyme treatment of the used cloths has given very promising results and may extend their useful life many-fold. Commercial application of this method is now being undertaken.

(ix) *Miscellaneous.*—Several projects in which the Section is particularly interested, and on which work has already commenced, could be given little attention during a year. These included study of the role of ascorbic acid in the deterioration of butter, the part played by phosphatide in the deterioration of several dairy products, and the phenomenon of bound phosphatase in flash-pasteurized cream.

At the request of the Army Department experiments have been conducted on the freezing of milk in small containers for transport overseas. Preliminary experiments indicate that this method, which was used successfully by the United States Armed Forces during the war, will also be applicable under the particular local conditions.

(x) *Publications.*—Papers published by this Section during the period covered by the report were:—

Conochie, J., and Wiley, W. J. (1946).—The maturing of cheddar cheese in pliofilm. *Aust. J. Dairy Tech.* 1: 87-90

Loftus Hills, G., and Conochie, J. (1946).—The mechanism of the oxidant effects of commercial salt and water in butterfat. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 414-29.

Loftus Hills, G., and Thiel, C. C. (1946).—The ferric thiocyanate method of estimating peroxide in the fat of butter, milk, and dried milk. *J. Dairy Res.* 14: 340-53.

Loftus Hills, G., and Wilkinson, R. (1946).—Note on the effect of phosphatide on the ferric thiocyanate method of estimating peroxide in fats. *J. Coun. Sci. Ind. Res.* (Aust.) 19: 430-1.

Morell, D. B., Conochie, J., and Loftus Hills, G. (1946).—Determination of the oxygen content of fats and oils. Ibid. 19: 190-4.

Pont, E. G. (1946).—The washing of butter and its effect on curd content and quality. Ibid. 19: 432-7.

—— (1947).—A self-cleaning cream separator. *Aust. J. Dairy Tech.* 2: 9-13.

2. *Radio Research Board.*—During the year the Radio Research Board continued its programme of investigations into the propagation of radio waves via the ionosphere. This programme has been carried out under the general direction of the Australian Radio Propagation Committee which was set up as a Committee of the Radio Research Board in November, 1942. This Committee has a membership representative of all the Fighting and Civil Services and all the Government research organizations carrying out work on radio propagation and allied phenomena.

The programme includes the installation and operation of ionospheric recording stations and the use of the information so obtained in the preparation of radio propagation data for use in connexion with the problems of high-frequency radio communication. These data are published monthly as Radio Propagation Bulletins, which are now available to the public.

The results of the programme of investigation and the application of the results have proved increasingly valuable to the Services and to civil radio communication organizations. More important still are the new discoveries that have been made regarding the nature of the ionosphere and the new lines of research that have been opened up by the developmental programme now that it has been thoroughly organized on a co-operative world-wide basis.

The Board's work has been carried out principally in the Electrical Engineering Department of the University of Sydney as in previous years. A second group has been working in the Physics Department of the University of Queensland for the past three years, and the Commonwealth Solar Observatory at Canberra has continued its long association with the Board's research programme.

Since December, 1945, the University of Tasmania has begun to share in the work of the Board by taking over the supervision of the ionosphere recorder at Hobart.

3. *Mineragraphic Investigations.*—Twenty-four investigations have been carried out into the mineral association of rocks, ores, and mill products submitted by mining organizations and institutions. Each investigation was directed to some specific problem relating to the occurrence or recovery of the valuable mineral. Six investigations were concerned with ores that were subjected to experimental treatment in the Melbourne Ore Dressing Laboratory or with the concentrates and tailings resulting from such treatment.

Investigations were made to determine the nature of the gold losses in tailings from the Great Boulder mine, the Maude and Yellow Girl gold mine, and a Hampton Plains mine. Incidentally, an unusual association of niccolite in a gold-bearing ore was discovered in the Hampton Plains mine, about five miles south-east of Coolgardie. Examination of the gold-antimony ore from the Blue Spec mine, Nullagine (Western Australia), showed in addition to free gold and stibnite, traces of gold and copper tellurides.

A microscopical examination of matters and speisses from the Broken Hill Associated Smelters at Port Pirie revealed a number of striking textures. It was

found that the artificial components in these products could be largely determined by the properties of known minerals together with inferences from equilibrium diagrams. A low-lead matte and a high-lead matte were found to differ essentially in the relative proportions of a copper-iron sulphide and a eutectic of copper-iron sulphide and a lead sulphide. A lead speiss contained two forms of iron arsenide, a copper arsenide, and a ternary eutectic, together with disseminated blebs of metallic lead and copper sulphide. An antimony speiss consisted largely of an arsenide and antimonide of iron and its eutectic with a probable alpha-iron, together with disseminated small particles of the iron sulphide known in meteorites as troilite.

A study of the Miocene sediments of the Aure Trough, Papua, was made for the companies engaged in oil search. The composition of the greywackes among these sediments is peculiar and consists essentially of angular grains of fairly fresh plagioclase and hornblende with varying proportions of rounded to angular fragments of igneous and sedimentary rocks set in a clay matrix. Quartz is notably lacking. The conclusion was reached that the bulk of the sediments was probably derived largely from the rapid erosion of relatively unconsolidated terrigenous andesitic tuffs.

An extensive petrological examination has been undertaken of the bauxite deposits of Tasmania. These deposits are widespread and fall into two groups, according to whether they overlie Jurassic dolerite or Tertiary basalt. The most important deposits occur at Ouse and St. Leonards overlying dolerite, and carry about 40 per cent. alumina. In profile they are characterized by a transition from a capping of iron-rich bauxite through a zone of earthy bauxite, relatively rich in alumina and poor in ferric iron, to a lower zone poorer in alumina and richer in iron.

These investigations have been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has also assisted by granting laboratory accommodation in the Geology School. Extensions to the Geology building are now in progress, and increased accommodation has been provided for the Mineragraphic Section.

4. *Ore-dressing Investigations.*—The co-operative investigations being carried out with the assistance of the Kalgoorlie School of Mines, the South Australian School of Mines and Industries, and the University of Melbourne were continued.

At Kalgoorlie, most attention was given to the cyanidation, amalgamation, &c., of gold ores and dumps. Materials examined came from Southern Cross, Linden, Evanston, Lockwood, Widgiemooltha, Kanowna, Lawlers, Fimiston, Kookynie, Cue, Youanmi and Kalgoorlie itself. One sample of vermiculite and one of clay were also examined.

At Adelaide the work was almost solely devoted to coal. An extensive investigation was made of various factors influencing the briquetting of fine coal from Leigh Creek (South Australia), particular attention being given to the size of coal, moisture content, briquetting pressure and the effect of changes in moisture content in storage. At the request of the Secondary Industries Division, Ministry of Post-war Reconstruction, the laboratory is now investigating some aspects of spontaneous heating in stored coal with particular reference to coal from the Blair Athol Field in Queensland.

In Melbourne, work on ilmenite-zircon-rutile sands from beaches in New South Wales, Queensland and Western Australia has continued. The appointment of a physicist to investigate the principles of electro-static separation, with special reference to beach sand treatment, has been approved, but no appointment has yet been made. Work on copper-gold, copper-nickel, tin and other base metal ores has been carried out, and there has been a mild revival of interest in gold ores and tailing dumps. Reports on gold ores from Mount Todd (Northern Territory) and Tawonga (Victoria) have been used in connexion with the design of new treatment plants. Variations in operating results at the Maude and Yellow Girl Mine, Gippsland, have been investigated with some success.

5. *Mathematical Statistics.*—The activities of the Section have continued generally along the lines of the previous year, assistance being provided in most sections of the Council's programme, to various government departments and the universities in the several States, and to commercial organizations and private individuals. Little improvement has occurred in the acquisition of trained staff, one appointment only having been made within the year. This results in restriction of scope almost entirely to work of an auxiliary and an advisory nature, and allows only limited opportunity for independent research.

In addition to the courses regularly contributed in the Mathematics Department of the University of Adelaide, where the Sectional head-quarters are housed, series of lectures in statistical method, with a bias in certain specified subjects, have been delivered at the request of other universities and organizations in the Commonwealth. Awareness of the statistical approach is obviously increasing, and it is hoped that the courses of lectures will give further stimulus to the subject.

The long-range project of determining the reliability of monthly rainfall in South Australia has been continued, and there remains to be completed only the analysis of rainfall records from districts west of Spencer's Gulf.

Investigation of the trend in yield throughout the wheat belt of South Australia has been almost finalized, and a full report is in process of preparation. At this juncture it is worth mentioning that approximately 25 per cent.—or, in absolute terms, 600,000 acres—of the total average annual acreage in the period examined, 1913-1937, shows definite evidence of declining yields. It has been decided to proceed further with this investigation in two directions, firstly, to follow in greater detail the trend of yield in the development of mallee wheat lands, and secondly, to extend the correlation analysis to study more closely the relationship between yield and rainfall.

Below are given briefly the projects of the various Divisions with which the Section has been associated during the year, either in designing the experiments concerned, analysis of results, or in advice on the form of their presentation.

(i) *Division of Animal Health and Production.*—Considerable interest has centred on wool biology. Certain results of the progeny tests have been prepared for publication, and further analyses carried out. Extensive studies have been made of the productivity levels of sheep as affected by plane of nutrition, and of their systematic reactions and wool production as affected by atmospheric temperature, fleece increment, &c. Effects of similar factors on water consumption were also noted.

In addition to routine analyses of field experiments concerned with parasitology, a further large-scale trial on the results of varying dosage rates of phenothiazine has reached a final stage.

The classing trial at Gilruth Plains has proceeded, and at the McMaster Field Station the effects of varying factors on measurements of sheep have been embodied in a report; here also results of sampling for fibre diameter, length and density of fleece were analysed.

(ii) *Division of Biochemistry and General Nutrition.*—The progress of a large-scale experiment on the effect of trace element deficiencies on sheep in South Australia has been followed, and some of the results analysed. Other work has concerned the concentration

of vitamin A in the blood of sheep; the interpretation of interactions in the analysis of yields of pasture treated with zinc, copper, cobalt, &c.; and the confidence limits for energy relationships.

(iii) *Dairy Research Section.*—Experiments were planned and some analyses carried out on the quality and durability of butter.

(iv) *Division of Economic Entomology.*—Co-operation with this Division is consistent and extensive. In addition to analysing results of regular dusting and spraying trials against insect pests, data on the retention of D.D.T. by cattle, the field distribution of grass grubs, an on the destruction of wood by termites, were handled, trapping experiments on blowflies planned, and consideration given to the general theory of host parasite relations.

(v) *Flax Research.*—Results from a number of agricultural trials, including resistance of different varieties to wilt, effect of fertilizers, physical characteristics of fibres attacked by rust, and three retting experiments were analysed, and those also from trials related to linseed oil contents, fibre percentages, tensile strengths and the effect of storage and exposure.

(vi) *Division of Food Preservation and Transport.*—Assistance was given in the designing of experiments on the dehydration of fruit, vegetables and meat, and with sampling problems occurring in fruit picking.

(vii) *Division of Forest Products.*—An increasing number of experiments have been designed and analysed for the Division of Forest Products, in addition to constant aid of an advisory nature in the many aspects of timber research. On the chemistry side, studies of pulp and paper have involved the effect on properties of various factors—method of washing pulp, addition of salts, buffering agents, and so on—and the effect of plate used in determining freeness. The accuracy of lignin determinations has been calculated, and the effect of particle size in determinations of the chemical composition of wood samples studied. Experiments have been planned for the Wood Structure Section, on dimensions and shrinkage of wood fibres, and the variation of the fibres with height in tree and distance from pith has been assessed. For Timber Physics, data on the reflectance of paints were analysed, and for Mechanics, results of tests on floors to determine effect of test position and joist spacing were similarly treated. For this Section also, correlations among properties were calculated for eucalypt species and certain other timbers, and the effect of locality, height and position in tree on the mechanical properties of some species was resolved. The efficiencies of various temperature and humidity conditions for drying wood were considered for the Seasoning Section, and the results of diffusion studies computed for Preservation. Among other experiments conducted by the Veneer and Gluing Section, were those on comparison of glues and gluing methods, and the effect of exposure and other treatments on plywood. Output and recovery results from a study of Victorian sawmills have been analysed for the Utilization Section of the Division, and investigations included also box and immersion tests, the relation between sawdust and quantity and type of production, and the treatment of spade handles.

(viii) *Division of Industrial Chemistry.*—Assistance provided to the Division of Industrial Chemistry has included the analysis of comparative cement tests with varying types of sand.

(ix) *Division of Plant Industry.*—The field design and analysis of several grazing trials were undertaken, and techniques for measurement of pasture characters developed for the Agrostology Section of the Division. Similar assistance, in respect of numerous species, cultivation and fertilizer trials, was given to Irrigation Centres and Plant Introduction. Experiments, involv drug plants and horticultural crops were designed, and the results computed; among these was a series of analyses of ascorbic acid content and other measures of potato quality. Other work included physical and chemical measures of apples, and date of picking in relation to their keeping quality, the protection of tomatoes and tobacco against virus transmission, and response to fertilizers in pine plantations.

(x) *Division of Soils.*—Attention has been directed to the expectation of rainfall in certain localities in South Australia, and the results of an experiment showing the effect of mechanical composition and nitrogen on water-stable aggregation have been analysed.

(xi) *Miscellaneous.*—Beyond Council projects, assistance has been provided during the year to the following:—*Australian Capital Territory*: Institute of Anatomy. *New South Wales*: Forestry Commission, Soil Conservation Service. *Queensland*: Sub-Department of Forestry. *South Australia*: Department of Agriculture, Department of Woods and Forests, South Eastern Drainage Board, Roseworthy Agricultural College, University of Adelaide, including Waite Agricultural Research Institute. *Victoria*: Forestry Commission, Department of Agriculture, Flax Production Committee, University of Melbourne, Joint Service Committee on Stores and Clothing, Royal Australian Air Force Repairs and Maintenance Directorate, Ministry of Munitions, Australian Forestry and Timber Bureau, Australian Paper Manufacturers Limited. *Western Australia*: University of Western Australia.

6. *Physical Metallurgy.*—(i) *General.*—This Section has now completed its first year of operation; it is housed in the Baillieu Laboratory in the University of Melbourne under the direction of Professor J. Neill Greenwood and in conjunction with the School of Metallurgy Research. Because of the close co-ordination of the work in the Laboratory it is thought advisable to give a general description rather than to mention just the results obtained by members of the Council's staff.

During the first year two organizational features have been most prominent, namely the selection of staff and the building up of equipment. Both are still proceeding.

(ii) *Programme.*—The immediate programme of the Section is concerned with the properties of metals and alloys at high temperatures. This involves first the technology of production of the metals and alloys, and second the construction of equipment to enable various physical properties to be determined at temperatures up to 1,000° C. (in most cases in a vacuum of 10^{-4} mm. of mercury). Ultimately, it is expected that alloys will be produced which are resistant to atmospheric attack up to this same temperature. Progress has been made in both directions. Titanium metal in powder form has been produced by the reduction of titanium tetrachloride with magnesium—the reaction taking place at about 900° C. This process is being operated on a semi-commercial scale by the United States Bureau of Mines at Salt Lake City, and this organization, through the Washington Liaison Office, has offered to supply titanium powder, the first batch of which has already been received. Although this metal is of a sufficient order of purity to form the basis for much exploratory work, it is hoped to develop a process which has been proved successful overseas, namely the conversion of the metal into the tetra iodide and the thermal decomposition of this. Preliminary experiments have been carried out along these lines.

Experience has also been gained in the technique of sintering the pressed powder and the susbequent mechanical working of the pellets. It has been shown that even in a vacuum of 10^{-4} mm. Hg contamination may occur. From the high melting point transition

elements, titanium has been selected because of its low specific gravity (4.5) and the existence of two allotropic forms with a transition at 880° C.

A high temperature vacuum dilatometer has been designed and is in course of construction and equipment for the thermal analysis of alloys in the solid state has been set up. Various types of equipment for sintering these alloys in vacuum have also been constructed, namely (*a*) a water-cooled sintering bell under which a bar up to 6 inches long by $\frac{3}{8}$ inch square can be heated by passage of a low voltage current through the bar as a resistor; (*b*) an evacuated silica tube heated by a resistance wound tube furnace; (*c*) a high frequency induction heater of 2 kw. capacity.

It is proposed to make an exploratory survey of the influence of other elements on the properties of titanium.

The work of the laboratory involves some complex analytical problems and the co-operation of the spectrographic section of the Munitions Supply Laboratories has been freely used.

Since most of the high melting point transition metals are highly reactive to atmospheric gases, it will be essential to develop a method for determining the gas content of alloys such as has been done overseas.

(iii) *Co-operation with other Laboratories.*—In the field of properties of metals the Section is co-operating with the Division of Aeronautics in designing, constructing and operating an X-ray crystal analysis set to study the nature of fatigue and creep in metals—both features being important in the failure of metals in aircraft and in gas turbines. Ultimately this work will link up with our high temperature alloy investigations. Co-ordinating conferences in the field of X-ray crystal analysis are being arranged with these laboratories interested in this work.

7. *Rubber (Guayule) Investigations.*—The study of the growth and rubber content of the guayule plant under Australian conditions began five years ago at the Waite Institute, Adelaide. A series of plots were laid down in various localities in South Australia, and analytical work has been continuously carried out in the laboratory. The continuance of this work has proceeded satisfactorily under the conditions outlined in the previous report of 1945-46 and the time is approaching when it will be possible to make interesting and important comparisons between results from the various plots. It is intended that as the plants in each area reach an age of five years from the date of sowing special samplings will be made to determine those cases in which further investigation would be profitable. This stage of the work will be completed by the end of 1948.

At present, plots are being maintained at seven different localities in South Australia, under widely divergent soil and climatic conditions. In some cases the plants are growing under entirely natural conditions of environment while in others varying numbers of irrigations are applied in the summer period. According to certain work carried out in the United States of America guayule produces its rubber during periods of dormancy which may be induced either by moderately low temperatures or periods of drought. These periods must not be too short. The whole behaviour of the plant appears to be influenced by soil conditions, temperatures of both soil and surrounding air and water supply, the latter having very considerable bearing on the rate and amount of rubber deposition. It has been shown that, depending on environmental conditions, the plant makes periodic flushes of growth during which the accumulation of dry matter outstrips the rate of deposition of rubber, particularly in the newer tissues. Lack of water slows down the growth and induces accumulation of rubber. To test this effect plots in the Murray Valley are supplied with a variable number of irrigations—five, three, two and nil—in the summer.

At the present stage interesting comparisons can be made between plants grown from seed produced from plants established at Canberra a considerable number of years ago and plants raised from seed of selected strains of guayule obtained from the United States during the early part of World War II. One of the main differences is the much larger size of the Canberra strain as against the smaller plants from the United States strain. This results in lower percentages of rubber from the larger plants than from the smaller ones but the yields expressed as total rubber per plant may approach one another more closely. However, in general, the United States strain appears to have the advantage and in addition it is possible to grow more plants per acre if closer spacings are used. It would seem that the development of a small, stocky, high-yielding strain of plant is desirable.

The intervals between samplings, are fixed at three, six, or twelve months according to the importance of the plots and the information desired. Where the plants grow relatively slowly it was only necessary to obtain data on the ultimate rubber content over a period of years, mainly for comparative purposes and such plots are being sampled once yearly. Other plots are sampled six-monthly to obtain information at an intermediate stage. It had been observed, however, that the growth of the plant and accumulation of rubber in its tissues did not follow a curve having a smooth upward trend but at intermediate stages there was a tendency for the curve to flatten out or even to fall before again rising. This is recognized as due to variations in environmental conditions, the ultimate general trend, however, being to rise with time. In important areas therefore the sampling periods have been reduced to intervals of three months in order to obtain more fundamental information. Plants have been in certain important cases separated into leaves, stems plus heads, and roots, for analysis to study the distribution of the rubber within the plant. Progressive weight increase, however, can only be estimated from the stem weights, since guayule is extremely prone to leaf fall, especially under dry conditions of growth; roots are not fully recoverable but results are valuable in assessing possible recoveries of rubber on a large scale.

The best results came from plots containing plants grown from the United States strain of seed at Loxton and Loveday in the light soils and warm climate of the Murray Valley. Plants of four to four and a half years of age receiving three irrigations per summer showed 7 to 8 per cent. of rubber corresponding to 77 grams of rubber per plant. Those receiving no irrigation for the past two summers yielded 9 per cent. rubber and a total of 50 grams per plant. By comparison, plants from Canberra-grown seed, under the same conditions, yielded considerably less. Controlled irrigation to enable growth of the plant but to place it periodically under conditions of stress yields the best figures. The results from the Morphett Vale planting, where conditions vary from wet cold winters to dry warm summers, are superior to those from the Murray Valley, both being without irrigation. There are, however, considerable variations in plant weights from different strains of seed. Calculated on a basis of one plant per square yard, which is a conservative estimate, the 77 grams obtained at Loxton corresponds to 830 lb. of rubber per acre.

In addition to the purely South Australian work, analyses have been carried out at the Waite Institute on material grown at Lawes, Queensland, and at Canberra under the control of the Plant Introduction Section of the Division of Plant Industry. The results

from Lawes compare favourably with those from the irrigated Loxton and Loveday plants in South Australia but, the plants being larger, both percentage rubber (5.31 per cent.) and total rubber per plant (69.1 grams) are less. Since the plants do not yet appear to have reached their maximum rubber content the work is proceeding for a further period.

8. *Oenological Research.*—(i) *Sherry Investigations.*—During the year, the investigation of factors which influence the growth and metabolism of the film-forming sherry yeasts has been continued. Particular attention has been given to the study of the accumulation of acetaldehyde in wines and artificial media under the influence of the yeasts, for this has been found to be closely related to the characteristic flavour and aroma of "fino" sherry.

In artificial media, the course of aldehyde accumulation has been found to be influenced by the type and amounts of the substances supplied as sources of carbon and nitrogen for the yeast film. This aspect of the subject is being studied further with wines and artificial media.

(ii) *Sweet Wine Investigations.*—Commencement of the full programme of investigations again had to be postponed this year. Owing to the abnormal weather experienced just prior to, and during the vintage season, the wine-makers who had agreed to co-operate in this work were unable to undertake the making of the experimental wines.

(iii) *Collection of Yeast Cultures.*—At the request of the Australian Wine Board, the Committee has extended its research programme to include the establishment of a collection of tested strains of wine yeasts, selected for Australian conditions and requirements. As a preliminary step to the establishment of such a collection, twelve strains of wine yeasts have been obtained from overseas collections and twenty have been isolated from local sources.

(iv) *Publication.*—The following paper was published during the year:—

Fornachon, J. C. M. (1946).—The pH of wines: examination of glass and quinhydrone electrode values. *Ind. Eng. Chem., Anal. Ed.* 18: 790-3.

XXI. INFORMATION SERVICE AND LIBRARY.

A. Information Service.

1. *General.*—Pending the provision of permanent office space at Head Office, the work of Information Service has been continued in temporary accommodation at 425 St. Kilda-road. In consequence, some additional duties have been incurred in general office routine, and in maintaining the flow of current journals and other library material to and from Head Office and other technical reference libraries. These additional duties have encroached considerably on the normal work of the staff. Also, although the principal abstracting, indexing, and reference books were brought with us on loan from Head Office Library, the separation from full library facilities has been a considerable handicap in dealing with certain types of inquiries.

The work has followed the general trend of the previous year with increasing emphasis on subjects related to secondary industry. Certain factors have prevented the implementation of some of the projects planned and it has been necessary to defer some of the more important work. Although some additional staff has been obtained, the demand for information has been greater than our capacity to deal with it.

The Officer-in-Charge attended the Royal Society Empire Scientific Conference, the British Commonwealth Scientific Official Conference, and the Imperial Agricultural Bureaux Conference in London in 1946, as a member of, and Secretary to, the Australian Delegation. Subsequently, he visited Canada and the United States of America for consultations with prominent workers in Information Services, and to obtain first-hand knowledge of the peace-time development of the British Commonwealth Scientific Office, Washington. A report was submitted, and recommendations made, to the Executive Committee of the Council, to implement certain recommendations of the British Commonwealth Official Scientific Conference.

The Officer-in-Charge has been appointed Australian Liaison Officer for the Imperial Agricultural Bureaux, and is responsible for all matters relating to the duties of official correspondents and for the distribution of Imperial Agricultural Bureaux publications and reports.

Information work requires the closest co-operation between the scientific and non-scientific staff and the team work of the staff has been most gratifying.

2. *Information Section.*—(i) *Head-quarters, Melbourne.*—(*a*) *General.*—While the prime function of the Section is the handling of inquiries, its activities have extended to cover related aspects of the general problem of dissemination of scientific and technical information. This is a natural development arising from the nature of the work and is in step with the general trend of overseas practice.

(*b*) *Inquiries (including Sydney Office).*—During the past year about 2,900 inquiries have been handled. Approximately 1,100 of these were of a minor nature such as could be summarily dealt with by telephone. A simple statistical record has been kept of the remainder, some 1,800, which may be termed major inquiries, and analysis of these for the period shows: (*a*) 6 per cent. from various Divisions and Sections of the Council, 16 per cent. from government departments, 30 per cent. from private individuals, and 43 per cent. from industry; (*b*) 74 per cent. received by Melbourne office and 26 per cent. by Sydney office; (*c*) 49 per cent. came from Victoria, 33 per cent. from New South Wales, and only 18 per cent. from the other States; (*d*) slightly less than 20 per cent. were referred to other appropriate authorities for reply direct; (*e*) the range of subjects is extensive but 34 per cent. of the major inquiries were associated with chemistry and chemical industries and 26 per cent. were related to agriculture and biology.

The procedure followed by the Section in the handling of inquiries has been crystallized in a production *Notes for the Guidance of Information Officers.* Although produced primarily for internal use, there has been a demand for copies on the part of external bodies interested in information work.

(*c*) *Technical reports.*—This work has been handicapped severely by shortage of staff, and it was thus deemed more important to maintain as far as possible, the standard of service given in dealing with inquiries than to attempt to produce reports (T-series). This is reflected in the fact that only one report (T4, Dingo Control in Australia, Jan., 1947) has been produced during the period. However, a comprehensive report on silicones is almost ready for reproduction.

(*d*) *Bibliographies and summaries of information.*—Late in 1946 it was decided that something should be done to permit the maximum advantage to be gained from the work involved in the production of bibliographies and summaries of information. Although normally prepared in the course of dealing with a specific inquiry, this material would, in many cases, be of quite wide interest. Accordingly, lists of subjects dealt with are now regularly published in a number of scientific, trade, and technical journals, with an intimation that copies are available.

So far 146 items have been so publicized, and the resulting requests have totalled 620. The range of subjects covered was wide, and requests were fairly well distributed.

(*e*) *Photostats.*—Where an inquirer is so situated that he does not have access to a library, or when it is desired to refer to inaccessible library material, it is usually necessary to send a photo copy of the reference. In the case of inquiries from private persons, it is now the custom to send this material on loan only. During the past year, a total of about 2,000 pages has been sent out.

(*f*) *Trade literature.*—There is a wide and still growing realization by technical information services of the value of trade literature. It is of special value to an information service, because this type of material is usually set out in readily assimilable form, and also because it is usually "live" and up to date. During the past year the Service has been accumulating such literature, in various forms, and so far over 600 pieces have been indexed and filed.

(*g*) *Abstracting of chemical literature.*—During the past year, the Service has prepared a total of 350 abstracts, covering everything of importance which has appeared in a wide range of Australian journals. The abstracts so prepared are published in supplement form by the Australian Chemical Institute in its Journal and Proceedings.

(*h*) *Dissemination of information from overseas.*—As mentioned in the previous report, the Service undertook to arrange for the extension to Australia of the facilities for access to results of war-time research afforded by the United States through the medium of the Department of Commerce. Minimum staff only has been used for this, but the volume of work has reached considerable proportions. Thus a total of 7,146 abstracts have been sent to journals for publication resulting in requests by industry and scientific establishments for 1,586 copies of complete reports, which have been either provided from local facilities or ordered overseas. In this work the Service has collaborated with the Secondary Industries Division of the Ministry of Post-war Reconstruction, and with the Munitions Supply Laboratories, Technical Information Section. The Industrial Information Advisory Committee set up to co-ordinate such activities of all three bodies, has held twenty meetings during the year and has developed into a body of actual, and great potential value in its work for Australian industry. A booklet *War-time Developments in Science and Technology,* describing these activities, was produced during the year on behalf of the Ministry of Post-war Reconstruction. Steps have also been taken to ensure that war-time research being published in Great Britain is afforded adequate publicity in Australia.

A further development in this field of activity has been the organizing of a scheme for the inter-change of information concerning current metallurgical research between the British Ministry of Supply on the one hand, and Australian Government departments and industrial undertakings on the other. Great interest has been shown in the project by those who propose to participate. A few British specimen reports have already arrived, and have been sent out. There are indications that inter-change of material of this kind on an intra-Empire basis will increase. The past year has seen the creation by the Service of at least the nucleus of an organization to handle it, and, what is more important, the Service has obtained the co-operation and confidence of the scientific and technical press which has provided the means of dissemination. This activity is now quite widely known and appreciated and can be developed further as the volume of incoming material increases.

(*i*) *Declassification of the results of Australian war-time research.*—The Service has also taken action, to some extent complementary to that described briefly above, to make available for inclusion in the United States Department of Commerce Bibliography of Scientific and Industrial Reports (referred to as the Office of Technical Services Bibliography), the results of such Australian war-time research activities as would not otherwise be published widely. These reports were hitherto unpublished because of security classifications.

(*ii*) *Sydney Office.*—By comparison with the previous year, when the office was established in its present form, the work of the Sydney Office has increased considerably. This is in part a natural development. However, it has been somewhat accelerated by the appointment of the Information Officer as Secretary of the New South Wales State Committee (in addition to his normal duties), and the consequent fusion of office facilities and certain of the activities involved. Thus there has been a marked increase, twelvefold, in the distribution of the Council's publications from this office.

Compared with last year, the number of enquiries for information has more than trebled. In all, more than 500 enquiries which necessitated written replies have been handled.

3. *Translation Section.*—The work of this Section can be considered under three main headings—

(*i*) *Foreign Journal Service.*— This is a carry-over from the war years. Until recently the section has been receiving from London, on microfilm, some of the back issues of the foreign scientific and technical journals in most demand. Translated contents sheets of these have been circulated, and photostats have been prepared on request. With the cessation of the flow of material, this work has been reduced to the handling of random requests for material in the possession of the Section. When it is known what published material of such war-time issues of these journals has been obtained by the libraries of the Council, the film sequences of some more important journals not so held will be completed.

(*ii*) *Translation.*—The demand for translation work has been heavy. The Section has met the position by scrutiny of material where possible, with the officer requiring the translation. Some material has been rejected as not meriting translation, some selected as meriting only translation in part, and in some cases oral translation has been sufficient, the officer concerned taking notes. During the year a translator was sent to Sydney to deal in this way with material accumulated by Divisions located there.

An important development has been in the amount of Swedish material for translation, particularly in the building, timber, and paper-making industries. As a result, provision has been made for the appointment of another translator, with Swedish as an essential language.

In spite of the amount of oral translation, and the other duties of the Section, the number of written translations made, of various lengths, has been about 80 for the year. The languages involved have been German, Russian, French, Swedish, Italian, Spanish, and Portuguese.

(*iii*) *Russian Scientific Literature.*— A development of the last year has been the commencement of a service designed to meet the difficulty of dealing with scientific and technical periodicals in the Russian language. Besides the language difficulty, there is also the problem of obtaining access to the material. Of the Russian journals that are received by the Council, a total of nineteen remain in the custody of Head Office Library. Commencing with these, a proposal was made to Divisions of the Council and appropriate Commonwealth and State bodies that translated contents sheets be distributed with a view to those interested making

requests for specific articles. The response was encouraging and the scheme was adopted. In addition to titles and authors, the contents sheets include summaries, sub-headings, and also the number of references, figures, tables, etc. Within the Council translations of specified articles are made on request, subject to the preliminary scrutiny as mentioned under paragraph (ii). The service has been well received outside the Council, and there are now 41 on the external mailing list for the contents sheets. On request photostats of articles are supplied (at cost) but translations are undertaken only within the Council.

4. *Cine-Photographic Section.*—Several requests and suggestions have been received from the Divisions and Sections of the Council for cinematograph work to be undertaken. It has been established that there is considerable scope for this work within the Council, as a recording method for certain research experiments, in addition to its better known applications in the production of films of an educational, documentary, or technical nature covering appropriate research projects. Proposals for the organization of this work are under consideration.

The film "Research Facilities of C.S.I.R." which was hurriedly produced last year for screening at the Royal Society and Official Conferences in London, has been shown to selected audiences in Great Britain, Canada, and United States of America.

At the request of the Chief, Division of Aeronautics, and in collaboration with his staff, a 25-minute 16 mm. black and white sound film entitled "Wings Under Test" has been produced. The film describes the equipment used and shows the methods of testing aircraft wings for conformation to airworthiness requirements, deterioration due to fatigue and, finally, the ultimate static strength by loading to destruction.

5. *Publications.*—The following papers were published during the year:—

Gillespie, D. T. C. (1946).—Vapour-liquid equilibrium still for miscible liquids. *Ind. Eng. Chem., Anal. Ed. 18*: 575-7.

Major, Beverly V. (1947).—Dingo control in Australia—A review of past action and future possibilities. Inf. Service Rept. No. T4.

B. Library.

The Council's library is somewhat different from any other in the Commonwealth in that it does not consist of one collection under one roof but of a number of separate units scattered throughout the Commonwealth. Each of the Divisions, Sections, and Research Stations has its individual collection of books, periodicals, and other library material, and, in fact, carries out all activities connected with the working of a research library. The work of these individual libraries is, however, co-ordinated in the Head Office library, where the main connecting link, the Union Catalogue, is maintained. In this Catalogue a record is kept of the holdings of all the other libraries no matter how large or how small. The maintenance of this Catalogue is becoming an ever increasing problem as each new sectional library is established, and the past year has seen a notable increase in the number of these libraries.

The Union Catalogue has proved its worth many times as it enables enquiries at Head Office library as to the availability in any of our libraries of books, periodicals, articles, serials, and certain types of pamphlet literature, to be answered in a few minutes. This service is readily available not only to all officers of the Council but to scientific research workers throughout the Commonwealth.

Taking the Council for Scientific and Industrial Research library as a whole, the subject matter covered would embrace with the exception of medical science practically the whole field of pure and applied science, but certain subjects are, of course, more adequately covered than others. During the last year efforts have been made to improve holdings in the subjects of textile technology, meteorological physics, and nuclear physics. In this work a special effort is made to obtain sets of bulletins, copies of monographs, and other important research material issued by Institutions and other world organizations doing similar work.

For the Union Catalogue to be a success it is necessary for the catalogue in all libraries to be uniform and according to accepted library rules. For this reason, *inter alia,* every effort is being made to staff the libraries of the Council with adequately trained librarians who have either studied for, or have passed, the examinations conducted by the Australian Institute of Librarians.

Work on the revised edition of the Catalogue of Scientific and Technical Periodicals is going on steadily. The task has proved even more formidable than was realized last year and it is not yet possible to predict when the Catalogue will be available for distribution.

XXII. FINANCIAL MATTERS, STAFF, AND PUBLICATIONS.

1. *Finance.*—The statement of expenditure from 1st July, 1946, to 30th June, 1947, is as follows:—

	£	£	£
1. Salaries and contingencies	..	..	89,597*
2. Remuneration of Chairman and Members of Council	..	..	3,470†
3. Investigations—			
(i) Animal Health and Production Problems	..	150,365	
Less contributions from—	£		
Wool Realization Fund	27,267		
Wool Research Fund	39,786		
Commonwealth Bank	2,700		
Department of Agriculture and Stock, Brisbane	1,000		
George Aitken Pastoral Research Trust	1,100		
Australian Cattle Research Association	3,750		
Australian Wool Board	35		
Australian Meat Board	323		
Alexander Fraser Memorial Fund	300		
Ian McMaster Estate	602		
Revenue Funds—			
Vaccine	1,888		
Pleuro Pneumonia	763		
Mastitis	742		
Toxaemic Jaundice—Barooga	321		
F.D. McMaster Field Station	300		
"Gilruth Planes" National Field Station	6,408		
Parkville	437		
		87,722	
			62,643

* The main items of expenditure under this heading are salaries of the Administrative staff at the Council's Head Office; salaries and expenses of officers at Australia House, London, and at Legation, Washington; staff and upkeep of State Committees; travelling expenses of Head Office staff, members of the Council, &c., and printing and general office expenditure.

† Provided from *Consolidated* Revenue Fund.

	£	£	£
(ii) Biochemistry and General Nutrition Problems		58,802	
Less contributions from—			
Commonwealth Bank	900		
George Aitken Pastoral Research Trust	900		
Wool Research Fund	14,051		
Wool Realization Fund	19,181		
		35,032	
			23,770
(iii) Plant Problems—Division of Plant Industry		119,442	
Less contributions from—			
Department of Supply and Shipping	634		
Department of Commerce and Agriculture	2,115		
Wool Research Fund	12,332		
Medicinal Plants Donations Fund	1		
Medicinal Plants Revenue Fund	2		
		15,084	
			104,358
(iv) Entomology Problems—Division of Economic Entomology		47,622	
Less contributions from—			
United Graziers Association	328		
		328	
			47,294
(v) Horticultural Problems of the Irrigation Settlements—			
(*a*) Citricultural—Research Station, Griffith	33,590		
Less contributions	10,581		
		23,009	
New South Wales Water Conservation and Irrigation Commission	2,536		
New South Wales Department of Agriculture	789		
Yenda Producers Co-operative Society Limited	105		
Leeton Fruit Growers Co-operative Company Limited	59		
Griffith Producers Co-operative Company Limited	316		
Rural Bank of New South Wales	1,052		
Leeton Co-operative Canneries Limited	631		
Griffith Revenue Fund	5,093		
(*b*) Viticultural—Research Station, Merbein	11,772		
Less contributions	3,617		
		8,155	
			31,164
Dried Fruits Control Board	1,200		
Irymple Packing Proprietary Limited	177		
Mildura Co-operative Fruit Company.	177		
Red Cliffs Co-operative Fruit Company	177		
Aurora Packing Proprietary Limited	176		
Merbein Research Station, Revenue Fund	1,710		
(vi) Soil Problems		33,182	
Less contributions from—			
Commonwealth Bank	2,000		
		2,000	
			31,182
(vii) Food Preservation and Transport Problems		47,063	
Less contributions from—			
Commonwealth Bank	2,400		
New South Wales Department of Agriculture	800		
Queensland Meat Industry Board	850		
Australian Meat Board	375		
Metropolitan Meat Industry Commission	500		
Egg Producers' Council	193		
Department of Commerce and Agriculture	2,201		
Apple and Pear Grant—Department of Commerce and Agriculture	95		
Food Preservation Revenue Fund	75		
		7,489	
			39,574
(viii) Forest Products Problems		87,608	
Less contributions from—			
Commonwealth Bank	2,000		
Australian Paper Manufacturers Ltd.	500		
Associated Pulp and Paper Mills Ltd.	500		
Australian Newsprint Mills Ltd.	500		
New Zealand Forest Products	250		
Miscellaneus contributions	51		
		3,801	
			83,807
(ix) Mining and Metallurgy		12,604	
Less contributions from—			
Australasian Institute of Mining and Metallurgy	368		
		368	
			12,236
(x) Radio Research		18,215	
Less contributions from—			
Postmaster-General's Department	4,500		
Departments of Army, Navy and Air	7,845		
		12,345	
			5,870
(xi) Information Service, including Library		20,395	
			20,395
(xii) Industrial Chemistry		132,246	
Less contributions from—			
Australian Cement Manufacturers Association	1,500		
Wool Research Fund	850		
		2,350	
			129,896

	£	£	£
(xiii) Fisheries Investigations	..	46,969	
Less contributions from—			
New South Wales Government	250		
Oyster Revenue Fund	150		
W/T Equipment *Warreen*	420		
		820	
			46,149
(xiv) Aeronautical Research	..	..	126,960
(xv) National Standards Laboratory	..	133,871	
Less contributions from—			
C.A. Corporation	352		
Wool Research Fund	2,122		
		2,474	
			131,397
(xvi) Building Materials Research	..	..	48,286
(xvii) Flax Research	..	13,974	
Less contributions from—			
Department of Supply and Shipping	11		
		11	
			13,963
(xviii) Radiophysics Laboratory	..	..	115,908
(xix) Tribophysics	..	..	27,506
(xx) Miscellaneous—			
(*a*) Dairy Research	..	6,512	
(*b*) Mathematical Research	..	11,628	
(*c*) Various	..	1,131 Cr.	
(*d*) Wool Use Promotion	..	675	
(*e*) Oenological Research	..	710	
		18,394	
Less contributions—			
Wool Research Fund	675		
Australian Wine Board	710		
		1,385	
			17,009
(xxi) Nuclear Energy Research	..	..	6,610
(xxii) Metallurgical Research	..	..	3,872
(xxiii) Meteorology Research	..	..	1,773
(xxiv) Overseas Studentships	..	6,839	
Less contributions from—			
Wool Research Fund	156		
		156	
			6,683
(xxv) Coal Dust Investigations	..	..	1,499
(xxvi) Unforeseen	..	..	330
(xxvii) Wool Textile Research	..	4,205	
Less contributions from—			
Wool Research Fund	4,205		
		4,205	
Total of Item 3—Investigations	..	..	1,140,134

2. *Contributions and Donations.*—The following statement shows the receipts and disbursements during the year 1946-47 of the funds provided by outside bodies and recorded in the special account established in 1931, entitled "The Specific Purposes Trust Account":—

	Receipts 1946-47 and balances brought forward from 1945-46.	Expenditure 1946-47.
	£	£
Wool Industry Fund Account	50,000	46,448*
Commonwealth Bank (Animal Health and Production, Horticultural, Food Preservation and Transport, and Forest Products Investigations)	10,091	10,000
Australian Wool Board (Animal Health and Production Investigations—Sheep Research)	2,514	36
Australian Cattle Research Association (Mastitis Investigations)	3,750	3,750
George Aitken Pastoral Research Trust (Animal Health and Production Investigations)	2,500	2,000
Queensland Government Cattle Research (Animal Health and Production Investigations—Sheep Research)	1,000	1,000
Australian Meat Board (Toxaemic Jaundice Investigations, Barooga, New South Wales)	135	135
Carried forward	69,990	63,369

* Expended as follows:—Capital improvements "Saumarez" Field Station—£381. Purchase cost "Saumarez" property, Armidale—£26,872. Preparation of site—Sheep Biology Laboratory, Prospect—£14. Erection of store and garage—O'Halloran Hill—£1,260. Purchase of O'Halloran Hill Remount Farm—£17,831. Preliminary costs—Erection of Nutrition Laboratory—£90.

	Receipts 1946-47 and balances brought forward from 1945-46.	Expenditure 1946-47.
	£	£
Brought forward	69,990	63,369
Australian Meat Board (Caseous Lymphadenitis Investigations—Animal Health and Production)	200	188
Alexander Fraser Memorial Fund	300	300
C.P.P. Fairbairn (Animal Health and Production Investigations—Foot-rot control)	30	..
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	1,124	602
University of Sydney—Provision of Laboratory Facilities (Animal Health and Production Investigations)	250	250A
Victorian Central Citrus Association—Citrus Problems (Plant Industry Investigations)	100	..
West Australian Golf Association (Plant Industry Investigations)	100	..
Tobacco Trust Fund—Prime Minister's Department and Department of Commerce—Tobacco Problems (Plant Industry Investigations)	10,173	2,115
Department of Supply and Shipping—Medicinal Plants (Plant Industry Investigations)	642	642B
Commonwealth Bank—Bee Research (Entomological Investigations)	92	..
Carried forward	83,001	67,466

A. Includes £250 on account of 1945-46 expenditure.
B. Includes £7 on account of 1945-46 expenditure.

	Receipts 1946-47 and balances brought forward from 1945-46.	Expenditure 1946-47.
	£	£
Brought forward ..	83,001 ..	67,466
United Graziers Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Economic Entomology)	500 ..	328
Australian Wheat Board—Wheat Infestation (Entomological Investigations)	17 ..	17C
New South Wales Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station)	2,000 ..	2,000
Murrumbidgee Irrigation Area Executive Committee Project Farm (Griffith Research Station)	100 ..	..
Department of Agriculture, New South Wales (Soils and Irrigation Extension Service, Griffith) ..	1,259 ..	851D
New South Wales Water Conservation and Irrigation Commission (Soils and Irrigation Extension Service, Griffith)	855 ..	577E
Griffith Producers' Co-op. Coy. Ltd. (Soils and Irrigation Extension Service, Griffith)	503 ..	340F
Rural Bank of New South Wales (Soils and Irrigation Extension Service, Griffith)	1,678 ..	1,133G
Yenda Producers' Co-op. Society Ltd. (Soils and Irrigation Extension Service, Griffith)	167 ..	113H
Leeton Fruit Growers' Co-op. Society Ltd. (Soils and Irrigation Extension Service, Griffith)	67 ..	67I
Leeton Co-op. Canneries Ltd. (Soils and Irrigation Extension Service, Griffith)	1,007 ..	680J
Mildura Co-operative Fruit Company (Dried Vine Fruits Investigations, Merbein)	185 ..	185K
Irymple Packing Coy. (Dried Vine Fruits Investigations, Merebein)	185 ..	185K
Red Cliffs Co-operative Fruit Company (Dried Vine Fruits Investigations, Merbein)	185 ..	185K
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	185 ..	185K
Dried Fruits Control Board (Dried Fruits Investigations) ..	1,200 ..	1,200
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations	288 ..	..
Australian Meat Board (Meat Investigations)	375 ..	375
Metropolitan Meat Industry Commissioner of New South Wales (Meat Investigations) ..	500 ..	500
Queensland Meat Industry Board (Meat Investigations) ..	850 ..	850
New South Wales Department of Agriculture (Food Investigations)	800 ..	800
A. Lawrence and Co. (Division of Food Preservation and Transport)	74 ..	..
W. Angliss Ltd. (Division of Food Preservation and Transport) ..	402 ..	..
L. Berger and Sons (Division of Food Preservation and Transport)	25 ..	..
Batlow Packing House Co-op. Ltd. (Division of Food Preservation and Transport—Fruit Juice Investigations)	210 ..	..
Ungars Peanuts Pty. Ltd. (Division of Food Preservation and Transport—Canning Investigations) ..	10 ..	..
Lewis Berger and Sons Ltd. (Division of Food Preservation and Transport—Fruit Juice Investigations)	25 ..	..
Carried forward ..	96,653 ..	78,037

C. Includes £17 on account of 1945-46 expenditure.
D. Includes £62 on account of 1945-46 expenditure.
E. Includes £41 on account of 1945-46 expenditure.
F. Includes £24 on account of 1945-46 expenditure.
G. Includes £82 on account of 1945-46 expenditure.
H. Includes £8 on account of 1945-46 expenditure.
I. Includes £7 on account of 1945-46 expenditure.
J. Includes £49 on account of 1945-46 expenditure.
K. Includes £8 on account of 1945-46 expenditure.

	Receipts 1946-47 and balances brought forward from 1945-46.	Expenditure 1946-47.
	£	£
Brought forward ..	96,653 ..	78,037
Horitz Fruit Drinks (Division of Food Preservation and Transport—Fruit Juice Investigations) ..	5 ..	..
Egg Producers' Council (Division of Food Preservation and Transport—Egg Investigations) ..	193 ..	193
Department of Commerce and Agriculture (Division of Food Preservation and Transport—Dehydration Investigations) ..	3,917 ..	3,917L
Australian Paper Manufacturers Limited (Paper Pulp Investigations)	500 ..	500
Associated Pulp and Paper Mills Limited (Paper Pulp Investigations)	500 ..	500
Australian Newsprint Mills Pty. Ltd. (Paper Pulp Investigations)	500 ..	500
Bureau of Forestry, Canberra, and Forest Services of Queensland, Victoria, New South Wales and Western Australia—Wood Structure (Forest Products Investigations)	75 ..	..
Annual Pulp and Paper Research Conference (Forest Products Investigations)	500 ..	500M
Sundry Contributions (Forest Products Investigations) ..	1,924 ..	51
Australasian Dairy Council (Wood Taint in Butter Investigations)	11 ..	..
Department of Supply and Shipping —Flax Processing (Forest Products Investigations)	17 ..	11
Brisbane Timber Merchants' Association (Division of Forest Products—Veneer and Gluing Work)	8 ..	..
Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations)	368 ..	368
Postmaster-General's Department (Radio Research)	4,500 ..	4,500
Department of Army, Navy, and Air (Radio Research) ..	9,000 ..	7,845
Sundry Contributions (Foreign Journal Service)	13 ..	..
New South Wales Government (Fisheries Investigations) ..	250 ..	250
Wireless Equipment M.V. *Warreen* (Fisheries Investigations)	420 ..	420
Drug Houses of Australia (Division of Fisheries—Agar Production)	25 ..	..
Commonwealth Fertilizers and Chemicals (Industrial Chemistry)	100 ..	..
National Gas Association (Gas Investigations—Industrial Chemistry)	1,033 ..	..
Australian Cement Manufacturers (Cement Investigations—Industrial Chemistry, National Standards)	1,650 ..	1,500
Department of Commerce (Apple and Pear Investigations) ..	150 ..	95
Ministry of Munitions	3,418 ..	3,418N
Department of Navy	5,064 ..	3,794
Sundry Contributors (Council for Scientific and Industrial Research —Publications)	24 ..	..
Amalgamated Textiles (Aust.) Ltd. (Division of Industrial Chemistry)	35 ..	..
Amalgamated Wireless (A/asia) Ltd. (Division of Industrial Chemistry)	31 ..	..
F. Walton and Co. (Division of Industrial Chemistry) ..	10 ..	..
Pope Products (Division of Industrial Chemistry)	25 ..	..
Associated Woollen and Worsted Textile Manufacturers of Australia (Division of Industrial Chemistry)	500 ..	..
Carried forward ..	131,419 ..	106,399

L. Includes £1,716 on account of 1945-46 expenditure.
M. Includes £250 on account fo 1945-46 expenditure.
N. Includes £3,418 on account of 1945-46 expenditure.

	Receipts 1946-47 and balances brought forward from 1945-46.	Expenditure 1946-47.
	£	£
Brought forward ..	131,419	106,399
Wool Scourers, Carbonizers and Fellmongers Federation of Australia (Division of Industrial Chemistry)	2,500	..
Kelsall and Kemp (Tas.) Ltd. (Division of Industrial Chemistry)	50	..
Alfred Lawrence and Co. Ltd. Division of Industrial Chemistry)	105	..
British Industrial Plastics (Plastics Research—Division of Industrial Chemistry) ..	50	..
R. Birch (Foundry Sands Investigations—Division of Industrial Chemistry)	3	..
Commonwealth Aircraft Corporation (Division of Metrology, N.S.L.)	1,519	352
Australian Wine Board—Oenological Research	872	848O
Revenue Fund—Toxaemic Jaundice Investigations (Animal Health and Production Investigations)	676	..
Revenue Fund—Contagious Pleuropneumonia Investigations (Animal Health and Production Investigations)	2,102	764
Revenue Fund—Helenslee Field Station (Animal Health and Production Investigations) ..	452	..
Revenue Fund—Oestrus Experiment (Animal Health and Production Investigations)	654	..
Revenue Fund—Sale of Contagious Pleuro-pneumonia Vaccine (Animal Health and Production Investigations) ..	3,335	1,889
Revenue Fund—Sale of Strain 19 Vaccine (Animal Health and Production Investigations) ..	581	..
Revenue Fund—Anaplasmosis Investigations (Animal Health and Production Investigations) ..	96	..
Revenue Fund—Parkville Laboratory (Animal Health and Production Investigations) ..	615	437
Revenue Fund—Tooradin Field Station (Animal Health and Production Investigations) ..	308	..
Revenue Fund—Poultry Breeding Investigations Werribee (Animal Health and Production Investigations)	125	..
Revenue Fund—Werribee Farm Mastitis Investigations (Animal Health and Production Investigations)	3,304	742
Revenue Fund—Drought Feeding Investigations, Werribee (Animal Health and Production Investigations)	63	..
Revenue Fund—National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations)	9,328	6,408
Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations)	469	..
Revenue Fund—Bacteriological Investigations (Animal Health and Production Investigations) ..	161	..
Revenue Fund—Parasitological Investigations (Animal Health and Production Investigations) ..	1,098	..
Revenue Fund—McMaster Laboratory Regional Pasture Research Station (Animal Health and Production Investigations) ..	86	..
Carried forward ..	159,971	117,839

	Receipts 1946-47 and balances brought forward from 1945-46.	Expenditure 1946-47.
	£	£
Brought forward ..	159,971	117,839
Revenue Fund—Infertility, F. D. McMaster Field Station (Animal Health and Production Investigations)	1,862	300
Revenue Fund—Toxaemic Jaundice Investigations, Barooga, New South Wales (Animal Health and Production Investigations)	631	253
Revenue Fund—Nutrition Laboratory (Biochemistry and General Nutrition Investigations) ..	1,167	..
Revenue Fund—Plant Industry Investigations	2,954	..
Revenue Fund—Medicinal Plants (Plant Industry Investigations)	6	2
Revenue Fund—Entomological Investigations	767	..
Revenue Fund—Griffith Research Station (Citricultural Investigations)	5,731	5,093
Revenue Fund—Merbein Research Station (Viticultural Investigations)	9,371	1,710
Revenue Fund—Division of Food Preservation and Transport ..	195	75
Revenue Fund—Egg Investigations, Egg Producers' Council (Division of Food Preservation and Transport)	147	..
Revenue Fund—Mining and Metallurgy	14	..
Revenue Fund—Ore-dressing Investigations	853	..
Revenue Fund—Fisheries Investigations	103	..
Revenue Fund—Oyster Investigations	218	150
Revenue Fund—Division of Aeronautics	147	..
Revenue Fund—Physics	517	..
Revenue Fund—National Standards Laboratory	33	..
Revenue Fund—Metrology ..	907	..
Revenue Fund—Dairy Investigations	9	..
Revenue Fund—Electrotechnology	110	..
Revenue Fund—Industrial Chemistry	470	..
Revenue Fund—Radiophysics ..	28	..
Revenue Fund—Merbein Research Station—Production of Pyrethrum	185	..
Revenue Fund—Information Service	76	..
Revenue Fund—Fellmongery Research	8	..
	186,480	125,422

3. *Wool Research Trust Account.*—A credit balance of £81,222 was brought forward from 1945-46 in the Wool Research Trust Account. A further £186,614 was received during 1946-47 from the Department of Commerce and Agriculture. Expenditure during 1946-47 was as follows:—

	£	£	£
Division of Animal Health and Production—			
McMaster Laboratory—Sheep Physiology Investigations ..	2,476		
McMaster Laboratory—Parasitology Investigations ..	2,948		
McMaster Laboratory—Dipping and External Parasites ..	1,563		
McMaster Laboratory—Wool Biology	4,806		
McMaster Laboratory—Biochemical Section	1,054		
McMaster Laboratory—Physiology and Reproduction ..	1,831		
McMaster Laboratory—Biochemistry and Parasitological	1,674		
Villawood—Fleece Analysis Laboratory .. .	7,503		

O. Includes £138 on account of 1945-46 expenditure.

	£	£	£
Prospect—Sheep Biology Laboratory	427		
Armidale—Parasitology Field Investigations	2,316		
Saumarez Field Station	3,733		
McMaster Field Station	158		
Animal Breeding Investigations	3,044		
Gilruth Plains—Capital	936		
Gilruth Plains—Annual	1,440		
Toxaemic Jaundice Investigations	1,744		
Survey of Wool Production	1,419		
Fellowship in Genetics and Animal Breeding	9		
Survey of Pastoral Problems in North-west of Australia	29		
Overseas Training for Officer	676		
		39,786	
Division of Plant Industry—Agrostology Investigations	12,333		
		12,333	
Division of Industrial Chemistry	850		
		850	
Division of Physics—Wool Research	2,122		
		2,122	
Division of Biochemistry and General Nutrition—Biochemical and Nutritional Investigations	14,051		
		14,051	
Miscellaneous—			
Overseas Studentships	156		
Textile Research	4,205		
Economic Survey of Woolgrowing in Kojonup Region of Western Australia	675		
		5,036	
			74,178
Grants from Wool Research Trust Account to Institutions undertaking wool research—			
Department of Agriculture, Western Australia—Sheep Infertility Investigation	1,365		
University of Western Australia — Investigations at Institute of Agriculture, Western Australia	2,200		
Gordon Institute of Technology—Fleece Analysis	1,500		
University of Melbourne—Survey of Wool Industry in Western District	2,750		
Roseworthy Agricultural College—Investigations	750		
		8,565	
Wool Research by Division of Agricultural Economics, Department of Commerce and Agriculture—Reimbursement of salaries and travelling expenses	1,105		
		1,105	
Purchase of Wool and Wool Top Samples	223		
		223	
Wool Consultative Council—Members fees and travelling expenses	122		
		122	
Miscellaneous	276*		
		276	
			10,291
			84,469

* Includes £141 expended by the Department of the Treasury, Canberra.

4. *Staff.*—The following is a list of the staff of the Council as at 30th June, 1947. The list does not include clerical staff, typists, laboratory assistants, and miscellaneous workers.

1. Head Office Staff.

(Head-quarters: 314 Albert-street, East Melbourne.)

Chief Executive Officer—A. E. V. Richardson, C.M.G., M.A., D.Sc.
Executive Officer—F. W. G. White, M.Sc., Ph.D.
Executive Officer—I. Clunies Ross, D.V.Sc.
Secretary—G. A. Cook, M.C., M.Sc., B.M.E.
Assistant Secretary—F. G. Nicholls, M.Sc.
Assistant Secretary—H. C. Forster, M.Agr.Sc., Ph.D.
Assistant Secretary—G. B. Gresford, B.Sc.
Assistant Secretary (Finance and Supplies)—M. G. Grace, A.I.C.A.
Consultant—G. Lightfoot, M.A.

Library—
Chief Librarian—Miss E. Archer, M.Sc.
Librarian—Miss A. L. Kent.
Librarian—Miss F. V. Murray, M.Sc.
Assistant Librarian—Miss J. Philip, B.Sc.

Accounts, Stores—
Accountant—D. J. Bryant, A.F.I.A.

Orders and Transport—
J. M. Derum.

Staff—
Staff and Industrial Officer—H. E. Waterman, A.F.I.A.
R. D. Elder.

Records—
P. Domec-Carre.
P. Knuckey.

Clerical Assistant to Chairman—Miss A. Slattery, B.A.
Architect—W. R. Ferguson, B.E.
Engineer—R. N. Morse, B.Sc., B.E.

Liaison Overseas—
London—
L. G. Dobbie, M.E.
D. T. C. Gillespie, M.Sc.
Washington—
N. A. Whiffen, F.S.T.C.
K. Loftus Hills, M.Agr.Sc.
Head Office—
Miss J. Dunstone, B.Sc., Dip. Ed.

Information Service—
Administration—
Officer-in-Charge—J. E. Cummins, B.Sc., M.S.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Records Officer—Mrs. G. M. Kilvington, M.Sc.
Information Section—
Senior Research Officer—C. M. Gray, O.B.E., M.Sc.
Senior Research Officer—D. T. C. Gillespie, M.Sc. (seconded).
Research Officer—G. J. Wylie, B.A., B.Sc.
Research Officer—Miss J. M. Baldwin, B.Sc., Dip.Ed.
Research Officer—Miss S. M. Andrews, B.Sc.
Research Officer—H. E. Booth, A.S.T.C.
Research Officer—Mrs. B. V. Major, B.Sc. (part-time).
Translation Section—
Senior Translator—A. L. Gunn.
Translator—E. Feigl, Ph.D. (Graz.).
Translator—Miss E. D. Armstrong, B.A. (Hons.)
Translator—Mrs. E. Notkin, M.D. (Prague) (part-time).
Editorial Section—
Editor of Publications—Miss M. E. Hamilton, B.Sc.
Film Section—
Research Officer—S. T. Evans, B.Sc.
Library—
Librarian—Miss J. Philip (on loan from H.O. Library).
Sydney Office—
Research Officer—A. M. Andrews, B.Sc.

2. Secretaries of State Committees.

New South Wales—
A. M. Andrews, B.Sc., Phillip House, 119 Phillip-street, Sydney.
Victoria—
F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.

Queensland—
Miss H. F. Todd, 113 Eagle-street, Brisbane.
South Australia—
J. Ward Walters, Division of Biochemistry and General Nutrition, University of Adelaide.
Western Australia—
R. P. Roberts, M.Sc. (Agric.), Department of Agriculture, Perth, Western Australia.
Tasmania—
F. J. Carter, c/o Premier's Office, Hobart.

3. Division of Plant Industry.

(Head-quarters: Canberra, A.C.T.)

At Canberra—
Administration—
Chief—B. T. Dickson, B.A., Ph.D.
Technical Secretary—W. Ives, M.Ec., A.I.C.A.
Librarian (half time)—Miss A. Nicholson (acting).
Senior Clerical Officer (half time).—K. J. Prowse.
Accountant (half time)—D. W. Banyard.
Plant Pathology—
Principal Research Officer—H. R. Angell, O.B.E., Ph.D.
Senior Research Officer—J. G. Bald, M.Agr.Sc., Ph.D.
Senior Research Officer—W. V. Ludbrook, M.S., B.Ag.Sc., Ph.D.
Research Officer—D. O. Norris, M.Sc. (Agric.).
Research Officer—Miss M. Mills, B.Sc.
Research Officer—J. H. E. Mackay, B.Sc.Agr.
Research Officer—Miss K. Helms, B.Sc.
Plant Introduction—
Senior Research Officer—W. Hartley, B.A., Dip. Agr.
Research Officer—C. A. N. Smith, B.Ag.Sc., R.D.A.
Horticultural Investigations—
Principal Research Officer—C. Barnard, D.Sc.
Medicinal and Drug Plant Investigations—
Senior Research Officer—K. L. Hills, M.Ag.Sc. (seconded).
Research Officer—Miss C. Rodwell, B.Sc.
Plant Physiology—
Research Officer—J. Calvert, D.Sc.
Research Officer—R. F. Williams (seconded).
Herbarium—
Research Officer—Miss N. T. Burbidge, M.Sc.
Agrostology—
Senior Principal Research Officer—J. Griffiths Davies, B.Sc., Ph.D.
Senior Research Officer—C. S. Christian, M.Sc.
Senior Research Officer—C. M. Donald, M.Agr.Sc.
Senior Research Officer—A. B. Cashmore, M.Sc. (seconded).
Research Officer—A. J. Anderson, B.Sc. (Agric.).
Research Officer—C. W. E. Moore, B.Agr.Sc.
Research Officer—K. D. McLachlan, B.Sc.Agr.
Research Officer—Miss H. R. Browne, B.Sc.
Research Officer—D. Spencer, B.Sc.
Research Officer—E. F. Biddiscombe, B.Sc. (Agric.)
Technical Officer—R. T. Milligan, Dip.Agr.D.
Technical Officer—R. E. Herrington, Q.D.H.
Technical Officer—D. V. Moye, H.D.A.
Technical Officer—G. R. Thomas, Q.D.A.H.
Technical Officer—L. J. Phillips, Q.D.D.M.
Technical Officer—C. S. McKay, Dip.Agr.D.
Agrostology, Weeds Physiology—
Senior Research Officer—C. G. Greenham, M.Sc.
Research Officer—P. Goldacre, B.Sc.
Agrostology, Weeds Ecology—
Research Officer—R. M. Moore, B.Sc.Agr.
Technical Officer—J. A. Robertson, Q.D.D.M.
Agrostology, Pasture Chemistry—
Research Officer—E. H. Kipps, B.Sc.
Technical Officer—F. K. Mayer, Q.D.A.
Tobacco Investigations—
Senior Research Officer—A. V. Hill, M.Agr.Sc.
Vegetable Investigations—
Senior Research Officer—E. M. Hutton, M.Sc., B.Agr.Sc.
Research Officer—D. C. Wark, M.Agr.Sc.
Research Officer—R. D. Brock, B.Agr.Sc.
Technical Officer—A. R. Peak, H.D.A.
Technical Officer—Miss J. A. Demaine, B.Agr.Sc.
Technical Officer—C. D. Mathews, R.D.A.

At Dickson Experiment Station, Canberra, A.C.T.—
Manager—L. Sharp, Dip.Agr.D.

At Cooper Laboratory, Queensland Agricultural High School and College, Lawes—
Senior Research Officer (agrostology)—T. B. Paltridge, B.Sc.
Research Officer (agrostology)—N. H. Shaw, B.Agr.Sc.
Research Officer (plant introduction)—S. G. Gray, B.Sc.Agr.
Research Officer (agrostology)—W. J. Bissett, B.Agr.Sc.
Research Officer (agrostology)—Miss H. Barford, B.Sc.
Technical Officer (plant introduction)—K. B. Anderssen, Q.D.A.
Technical Officer (plant introduction)—W. G. Robertson, Q.D.A. (on study leave).
Technical Officer (agrostology)—H. J. Wyndham, Q.D.D.H.
Technical Officer (agrostology)—R. Milford, Q.D.A.
Technical Officer (agrostology)—J. G. Downing, Q.D.A.H.
Technical Officer (agrostology)—R. J. Pack, Q.D.A.
Technical Officer (agrostology)—T. W. Elich, Dip. Col. Ag. (Holland).

At "Gilruth Plains", Cunnamulla, Queensland—
Technical Officer (agrostology)—G. H. Allen, G.D.A.
Technical Officer (agrostology)—C. I. Robertson, Q.D.H.
Technical Officer (agrostology)—A. Callender, H.D.A.

At Stanthorpe, Queensland—
Senior Research Officer (horticultural investigations)—L. A. Thomas, M.Sc.

At Nambour, Queensland—
Technical Officer (horticultural investigations)—G. P. Kelenyi, Dip.Agr.D.

At Brisbane, Queensland—
Senior Research Officer (plant introduction)—J. F. Miles, B.Agr.Sc.
Technical Officer (native plants investigation)—L. J. Webb.

At the University of Western Australia, Perth, Western Australia—
Research Officer (plant introduction)—E. T. Bailey, B.Sc.
Research Officer (agrostology)—R. C. Rossiter, B.Sc. (Agric.).
Research Officer (agrostology)—H. L. Pennington, B.Sc. (Agric.).

At Falkiner Memorial Field Station, Deniliquin, New South Wales—
Senior Research Officer (agrostology)—R. W. Prunster, B.Sc. (Agric.).
Research Officer (agrostology)—A. L. Tisdall, M.Agr.Sc.

Research Officer (agrostology) — W. M. Willoughby, B.Sc.Agr.
Research Officer (agrostology)—O. B. Williams, B.Agr.Sc.
Technical Officer (agrostology)—K. R. Brown, Dip.Agr.D.
Station Manager—G. A. Vasey.
Clerical Officer—S. J. Cossar.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Research Officer (agrostology)—R. Roe, B.Sc. (Agric.).
Research Officer (agrostology)—E. J. Hilder, B.Sc. (Agric.).
Technical Officer (agrostology)—R. G. Wilson, Q.D.D.M.

At Huonville, Tasmania—
Senior Research Officer (horticultural investigations) —D. Martin, B.Sc. (seconded).

At Katherine Experiment Farm, Northern Territory—
Farm Manager—F. Kent, H.D.A.

At State Experiment Farm, Trangie, New South Wales—
Technical Officer (agrostology)—R. J. Hutchings, Dip.Agr.D.

At Waite Agricultural Research Institute, Adelaide, South Australia—
Research Officer (gummosis investigations)—Miss J. Grace, B.Sc.Agr.

Northern Australia Regional Survey—
Research Officer—W. Arndt, B.Agr.Sc.
Supply and Transport Officer—H. J. Mason.

4. Division of Economic Entomology.

(Head-quarters: Canberra, A.C.T.)

At Canberra—

Administration—
Chief—A. J. Nicholson, D.Sc.
Principal Research Officer—F. N. Ratcliffe, B.A.
Librarian (half time)—Miss A. Nicholson.
Senior Clerical Officer (half time)—K. J. Prowse.
Accountant (half time)—D. W. Banyard.

Biological Control and Museum—
Senior Research Officer—F. Wilson.
Research Officer—T. G. Campbell.
Research Officer—S. J. Paramonov, D.Sc.
Research Officer—E. F. Riek, M.Sc.
Research Officer—D. H. Colless, B.Sc.Agr.
Research Officer—Miss M. Crust, B.Sc.
Technical Officer—A. T. Mills.

Physiology and Toxicology—
Senior Research Officer—D. F. Waterhouse, M.Sc.
Research Officer—M. F. Day, B.Sc., Ph.D.
Research Officer—D. Gilmour, M.Sc.
Research Officer—R. H. Hackman, M.Sc. (abroad; seconded from Division of Industrial Chemistry).
Research Officer—R. W. Kerr, B.Sc.
Research Officer—R. F. Powning, A.S.T.C.
Technical Officer—J. H. Calaby.

Locust and Pasture Pests—
Senior Research Officer—K. H. L. Key, M.Sc., Ph.D., D.Sc., D.I.C.
Research Officer—L. R. Clark, M.Sc.
Research Officer—P. B. Carne, B.Agr.Sc.
Technical Officer—D. L. Hall, Dip.Agr. (on rehabilitation study leave).

Vegetable Pests and Virus Vector Investigations—
Research Officer—G. A. H. Helson, M.Sc.
Research Officer—T. Greaves.
Technical Officer—N. E. Grylls, Dip.Agr.D.

Termite Investigations—
Research Officer—F. J. Gay, B.Sc., D.I.C.

At State Animal Health Station, Yeerongpilly, Queensland—

Veterinary Entomology (including Cattle Tick, Buffalo Fly, Sheep Blowfly, and Sandfly Investigations)—
Senior Research Officer—L. F. Hitchcock, M.Sc.
Senior Research Officer—K. R. Norris, M.Sc.
Research Officer—Mrs. M. J. Mackerras, M.Sc., M.B.
Research Officer—W. J. Roulston, B.Sc.
Research Officer—G. J. Snowball, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.

In Western Australia—
Earth-mite Investigations—
Research Officer—M. M. H. Wallace, B.Sc.

At Trangie, New South Wales—
Locust Investigations—
Technical Officer—L. J. Chinnick, Dip. Agr.

5. Division of Animal Health and Production.

(Head-quarters: Cr. Flemington-road and Park-street, Parkville, Melbourne.)

At Animal Health Research Laboratory and Divisional Head-quarters, Melbourne—
Chief—L. B. Bull, D.V.Sc.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.
Officer-in-Charge—A. W. Turner, O.B.E., D.Sc., D.V.Sc.
Principal Research Officer (bacteriology)—T. S. Gregory, B.V.Sc., Dip. Bact.
Principal Research Officer (pathology, bacteriology, dairy cattle)—D. Murnane, B.V.Sc.
Senior Research Officer (serological investigations)—A. D. Campbell, L.V.Sc.
Senior Research Officer (physiology)—R. H. Watson, D.Sc.Agr.
Senior Research Officer (immuno-chemistry)—A. T. Dann, M.Sc.
Senior Research Officer (chemical pathology and bacteriology)—A. T. Dick, M.Sc. (abroad).
Research Officer (bacteriology, dairy cattle)—E. Munch-Petersen, M.Sc., Ph.B.
Research Officer (poultry breeding investigations)—F. Skaller, B.Agr.Sc.
Research Officer (bacteriology, anaerobic infections)—A. W. Rodwell, M.Sc. (abroad).
Research Officer (chemical pathology and analytical chemistry)—J. B. Bingley, D.A.C.
Research Officer—Miss C. E. Eales, B.Sc.
Research Officer—Miss M. J. Monsbourgh, B.Sc.
Research Officer—H. G. Turner, B.Agr.Sc.
Research Officer—G. Alexander, B.Agr.Sc.
Technical Officer—M. W. Mules.
Technical Officer—E. Wold.
Technical Officer—A. E. Wright.
Technical Officer—J. J. Spencer.
Technical Officer (animal husbandry)—L. C. Gamble.
Clerk—J. J. Foley.
Librarian—Miss F. V. Murray, M.Sc. (part-time).

At F. D. McMaster Animal Health Laboratory, Sydney—
Officer-in-Charge—D. A. Gill, M.R.C.V.S., D.V.S.M.
Senior Research Officer (parasitology)—H. McL. Gordon, B.V.Sc.
Senior Research Officer (biochemistry)—M. C. Franklin, M.Sc., Ph.D.
Senior Research Officer (field investigations, ecto-parasites)—N. P. H. Graham, B.V.Sc.

Senior Research Officer (parasitology)—W. P. Rogers, M.Sc., Ph.D.
Senior Research Officer (bacteriology)—D. F. Stewart, B.V.Sc., Dip. Bact.
Research Officer (biochemistry)—C. R. Austin, M.Sc., B.V.Sc. (abroad).
Research Officer (physiology)—W. K. Whitten, B.V.Sc.
Research Officer (biochemistry)—R. L. Reid, B.Sc.Agr. (abroad).
Research Officer (ectoparasites)—Miss T. M. Scott, B.Sc.
Research Officer (parasitology)—Miss P. M. Sambell, B.A.
Research Officer (parasitology)—Miss M. Lazarus, B.Sc.
Research Officer (parasitology)—A. C. Jennings, B.Sc.
Research Officer (biochemistry)—Mrs. V. C. McClymont, B.Sc.
Technical Officer—E. A. Parrish.
Technical Officer—H. A. Offord.
Technical Officer—F. J. Hamilton.
Technical Officer—H. V. Whitlock.
Clerk—H. H. Wilson.
Librarian—Miss A. G. Culey, M.Sc.

At Wool Biology Laboratory, Sydney—
Officer-in-Charge (wool biology)—H. B. Carter, B.V.Sc.
Research Officer (wool biology)—Miss M. Hardy, M.Sc.
Research Officer (wool biology)—K. Ferguson, B.V.Sc.
Research Officer (wool biology)—Miss P. Davidson, B.Sc.

At Fleece Analysis Laboratory, Villawood, New South Wales—
Officer-in-Charge (wool metrology)—N. F. Roberts, M.Sc.
Research Officer (wool metrology)—L. T. Wilson, B.Sc.
Research Officer (fleece analysis)—A. J. Low, B.Sc.
Technical Officer—Miss L. Folley.
Technical Officer—Miss R. Cornforth.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Officer-in-Charge (parasitology, field studies)—I. L. Johnstone, B.V.Sc.

At F. D. McMaster Field Station, Badgery's Creek, New South Wales—
Officer-in-Charge (animal genetics)—R. B. Kelley, D.V.Sc.
Senior Research Officer (beef cattle production)—W. A. Beattie, B.A., LL.B.
Senior Research Officer (wool production)—J. H. Riches, B.Sc.(Agric.), Ph.D.
Research Officer (sheep breeding)—R. H. Hayman, B.Agr.Sc.
Research Officer (sheep breeding)—R. A. Bettenay, B.Sc. (Agric.)
Technical Officer—J. E. Gray.
Technical Officer—P. B. Sutton.

At National Field Station "Gilruth Plains", Cunnamulla, Queensland—
Officer-in-Charge (sheep breeding)—J. F. Kennedy, M.Agr.Sc.
Technical Officer (overseer)—I. D. B. Yuille.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Research Officer (biochemistry)—A. B. Beck, M.Sc.

6. Division of Biochemistry and General Nutrition.

(Head-quarters: at University of Adelaide.)

Chief—H. R. Marston.
Divisional Secretary—J. Ward Walters.
Principal Research Officer—A. W. Peirce, D.Sc.
Senior Research Officer—E. W. Lines, B.Sc.
Senior Research Officer—H. J. Lee, B.Sc.
Senior Research Officer—D. S. Riceman, M.Sc., B.Agr.Sc.
Research Officer—G. B. Jones, M.Sc.
Research Officer—F. V. Gray, M.Sc.
Research Officer—I. G. Jarrett, M.Sc.
Research Officer—T. A. Quinlan-Watson, M.Sc.
Research Officer—Miss S. H. Allen, B.Sc.
Research Officer—Miss P. Macbeth, B.Sc.
Research Officer—A. F. Pilgrim, B.Sc.
Technical Officer—D. W. Dewey.
Technical Officer—G. W. Bussell.
Technical Officer—J. O. Wilson.
Technical Officer—C. E. Sleigh.
Technical Officer—R. F. Trowbridge.
Technical Officer—D. F. Graham.
Technical Officer—V. A. Stephen.
Technical Officer—T. M. Rilstone.
Farm Manager—R. H. Jones, R.D.A.
Assistant Librarian—Miss I. Sanders, B.A.

7. Division of Soils.

(Head-quarters: at Waite Agricultural Research Institute, Adelaide.)

Administration—
Chief—J. A. Prescott, C.B.E., D.Sc. (part-time).
Deputy Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.*

Soil Survey Section—
Senior Research Officer—C. G. Stephens, M.Sc.
Research Officer—R. Brewer, B.Sc.
Research Officer—E. J. Johnston, B.Sc.Agr.
Research Officer—T. Langford Smith, M.Sc. (seconded).
Research Officer—K. H. Northcote, B.Agr.Sc.
Research Officer—G. A. Stewart, B.Agr.Sc.
Research Officer—K. D. Nicholls, B.Sc., B.Agr.Sc.
Research Officer—G. Blackburn, B.Agr.Sc.
Research Officer—R. A. Perry, B.Sc.
Research Officer—G. W. Cochrane, M.Sc.
Research Officer—E. W. Boehm, B.Sc. (Agric.).
Research Officer—H. T. Hughes, B.Ag.Sc.
Draughtsman—P. D. Hooper.
Technical Officer—L. W. Pym, R.D.A. (on leave).
Technical Officer—C. H. Thompson, G.D.A.

Soil Physics Section—
Senior Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Research Officer—G. D. Aitchison, B.E.
Research Officer—G. B. Clarke, B.Sc.
Research Officer—G. B. Stirk, B.Sc.
Research Officer—K. Norrish, M.Sc.
Research Officer—J. P. Quirk, B.Sc.Agr.
Technical Officer—C. G. Gurr, B.Sc.
Technical Officer—A. W. Palm.

Soil Chemistry Section—
Senior Research Officer—C. S. Piper, D.Sc. (part-time).
Research Officer (spectrography)—A. C. Oertel, M.Sc.
Research Officer—H. C. T. Stace, B.Sc.
Research Officer—B. M. Tucker, B.Sc.
Research Officer—R. S. Beckwith, B.Sc.
Research Officer—J. T. Hutton, B.Sc.
Technical Officer—Miss B. R. Begg, B.Sc.

* Appointed as Chief from 1st July, 1947.

Soil Microbiology—
Research Officer—T. H. Strong, M.Agr.Sc. (seconded).
Research Officer—Miss M. P. Thomas, B.Sc. (on leave).
Research Officer—J. R. Harris, B.Sc.
At Hobart—
Research Officer (soil surveys)—G. D. Hubble, B.Ag.Sc.
At Perth—
Research Officer (soil surveys)—R. Smith, B.Sc. (Agric.).
At Canberra—
Research Officer (soil surveys)—R. G. Downes, M.Agr.Sc.
At Deniliquin—
Research Officer (soil surveys)—B. E. Butler, B.Sc.(Agric.).
Rubber Investigations—
Research Officer—R. E. Shapter.

8. Irrigation Settlement Problems.

At Irrigation Research Station, Griffith—
Officer-in-Charge—E. S. West, B.Sc., M.S.
Senior Research Officer—R. R. Pennefather, B.Agr.Sc.
Senior Research Officer—D. V. Walters, M.Agr.Sc.
Chemist—N. G. Cassidy, M.Sc.
Plant Physiologist—R. F. Williams, M.Sc.
Research Officer—O. Perkman, B.Sc.Agr.
Research Officer—V. J. Wagner, B.Agr.Sc.
Research Officer—Mrs. Joan Tully, B.Sc., Ph.D.
Research Officer—K. Spencer, B.Sc.Agr.
Research Officer—A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D.
Research Officer—L. F. Myers, B.Agr.Sc.
Research Officer—H. J. Frith, B.Sc.Agr.
Research Officer—E. L. Greacen, B.Sc.Agr. (absent on studentship).
Assistant Plant Physiologist—C. T. Gates, B.Sc.Agr.
Senior Technical Officer—B. H. Martin, H.D.A.
Technical Officer—Miss Z. Lasscock.
At Commonwealth Research Station, Merbein—
Officer-in-Charge—A. V. Lyon, M.Agr.Sc.
Principal Research Officer—E. C. Orton, B.Sc.
Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Research Officer—G. V. F. Clewett, B.E.
Research Officer—W. J. Webster, B.Sc.
Research Officer—A. J. Antcliff, B.Sc.
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—S. F. Bridley, B.Agr.Sc.
Technical Officer—J. E. Giles.
District Officer (Nyah-Woorinen)—R. C. Polkinghorne (part-time).
District Officer (Wakool)—H. Jackson (part-time).

9. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant to Chief—C. S. Elliot, B.Sc.
Assistant to Chief—H. E. Dadswell, D.Sc.
Librarian—Miss M. I. Hulme.
Assistant Librarian—Miss N. Brunskill.
Clerk—A. D. Rampling.
Draughtsman—L. Santer, Dip.Eng.
Wood Structure Section—
Principal Research Officer-in-Charge—H. E. Dadswell, D.Sc.
Research Officer—H. D. Ingle, B.For.Sc.
Research Officer—Miss M. M. Chattaway, B.A., B.Sc., D.Phil.
Research Officer—G. L. Amos, M.Sc.
Research Officer—I. J. W. Bisset, B.Sc.
Research Officer—A. B. Wardrop, M.Sc. (abroad).
Technical Officer—Miss F. V. Griffin.
Photography—
Technical Officer—E. S. Smith.
Technical Officer—Miss A. M. Lightfoot.
Technical Officer—W. G. Hastie.
Wood Chemistry Section—
Principal Research Officer-in-Charge—W. E. Cohen, D.Sc.
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil. (seconded).
Senior Research Officer—D. E. Bland, M.Sc.
Research Officer—D. H. Foster, M.Sc.
Research Officer—A. J. Watson, A.M.T.C.
Research Officer—Miss C. M. Emery, B.Sc.
Technical Officer—A. G. Charles.
Technical Officer—Miss J. Meade.
Technical Officer—Miss G. Schwerin, B.S.
Research Chemist—C. M. Stewart, B.Sc. (on loan from Associated Pulp and Paper Mills Ltd.).
Timber Physics Section—
Senior Research Officer-in-Charge—R. S. T. Kingston, B.Sc., B.E.
Research Officer—L. N. Clarke, B.Eng.Sc.
Research Officer—G. A. Forster, B.Sc.
Technical Officer—I. G. Scott, F.M.T.C.
Technical Officer—A. Ack Hing, A.S.M.B.
Technical Officer—N. C. Edwards.
Timber Mechanics Section—
Senior Research Officer-in-Charge—K. L. Cooper, M.A., B.Sc.
Research Officer—C. E. Dixon, M.Sc.
Research Officer—N. H. Kloot, B.Sc.
Research Officer—R. G. Pearson, B.C.E.
Technical Officer—J. J. Mack.
Timber Seasoning Section—
Senior Research Officer-in-Charge—G. W. Wright, B.E.
Research Officer—J. W. Gottstein, B.Sc.
Research Officer—C. V. Lansell, B.Eng.Sc.
Technical Officer—H. D. Roberts.
Technical Officer—L. J. Brennan.
Technical Officer—J. K. Pinkerton, A.S.T.C.
Timber Preservation Section—
Senior Research Officer-in-Charge—N. Tamblyn, M.Sc. (Agric.).
Research Officer—R. W. Bond, B.Sc.
Research Officer—G. W. Tack, B.Agr.Sc.
Research Officer—G. N. Christensen, B.Sc.
Technical Officer—T. A. McLelland, A.S.M.M.
Technical Officer—A. Rosel.
Technical Officer—Miss N. Robinson.
Veneer and Gluing Section—
Senior Research Officer-in-Charge—A. Gordon, B.Sc. (seconded).
Research Officer (acting-in-charge)—H. G. Higgins, B.Sc.
Research Officer—A. W. Rudkin, B.Sc.
Research Officer—K. F. Plomley, B.Sc.Agr.
Timber Utilization Section—
Principal Research Officer-in-Charge—R. F. Turnbull, B.E. (seconded).
Senior Research Officer (acting-in-charge) G. W. Wright, B.E.
Research Officer—A. E. Head, B.Sc.
Research Officer—C. H. Hebblethwaite, Dip.For.
Technical Officer—R. G. Skewes, A.F.T.C.
Maintenance Section—
Technical Officer—S. G. McNeil.

10. Division of Food Preservation and Transport.

(Head-quarters: at State Abattoir, Homebush Bay. Postal Address: Private Bag, Homebush P.O.).

Administrative and General—
Chief—J. R. Vickery, M.Sc.,Ph.D.
Divisional Secretary—R. B. Withers, M.Sc., Dip. Ed.
Librarian—Miss B. Johnston, B.Sc.
Maintenance Engineer—T. L. Swan.

Physics Section—
Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Research Officer—M. C. Taylor, M.Sc.
Research Officer—G. M. Rostos, Dipl.Ing.
Technical Officer—M. B. Smith, A.S.A.S.M.
Technical Officer—J. Mellor (on leave).

Microbiology Section—
Senior Research Officer—W. J. Scott, B.Agr.Sc.
Research Officer—M. R. J. Salton, B.Sc.Agr.
Technical Officer—P. R. Maguire.
Technical Officer—D. F. Ohye, Dip.Ind.Chem.

General Chemistry Group—
Senior Research Officer—F. E. Huelin, B.Sc., Ph.D.
Research Officer—H. A. McKenzie, M.Sc.
Research Officer—Miss A. White, B.Sc.
Technical Officer—R. A. Gallop, A.S.T.C.

Fruit Storage Section—
Senior Research Officer—R. N. Robertson, B.Sc., Ph.D.
Research Officer—E. G. Hall, B.Sc.Agr.
Research Officer—J. F. Turner, B.Sc.
Research Officer—Miss M. Wilkins, B.Sc.

Canning and Fruit Products Section—
Senior Research Officer—L. J. Lynch, B.Agr.Sc.
Senior Research Officer—W. A. Empey, B.V.Sc.
Research Officer—J. F. Kefford, M.Sc.
Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—V. M. Lewis, B.Sc.Agr. (on leave).
Research Officer—B. V. Chandler, B.Sc.
Technical Officer—P. C. O. Thompson, A.S.T.C.
Technical Officer—R. Allan (seconded from Division of Fisheries).

Dried Foods Section—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil. (seconded from Division of Forest Products).
Senior Research Officer—A. Howard, M.Sc.
Research Officer—H. S. McKee, B.A., D.Phil.
Research Officer—A. R. Prater, B.Sc.Agr.
Research Officer—D. McG. McBean, B.Sc.
Research Officer—J. Shipton, B.Sc.Agr.

Meat Investigations (at Brisbane Abattoir)—
Senior Research Officer—A. R. Riddle, A.B., M.S.
Research Officer—W. R. Carter, B.E., B.Sc.
Technical Officer—H. J. E. Prebble, Dip.Ind.Chem.

At Australia House, London—
Senior Research Officer—N. E. Holmes, B.E.E., M.Mech.E.

11. Division of Fisheries.

(Head-quarters: Cronulla, New South Wales).

At Head-quarters—
Chief—H. Thompson, M.A., D.Sc.
Senior Research Officer (bacteriologist)—E. J. Ferguson Wood, M.Sc., B.A.
Senior Research Officer (biologist)—A. G. Nicholls, B.Sc., Ph.D.
Research Officer (biologist)—G. L. Kesteven, B.Sc.
Research Officer (chemist and hydrologist)—D. J. Rochford, B.Sc.
Research Officer (biologist)—Mrs. L. M. Willings, B.A.
Research Officer (biologist)—J. A. Tubb, M.Sc. (seconded).
Research Officer (biologist)—I. S. R. Munro, M.Sc.
Research Officer (biologist)—W. S. Fairbridge, M.Sc.
Research Officer (ichthyologist)—A. M. Rapson, M.Sc.
Research Officer (algologist)—Mrs. V. Jones, M.Sc.
Technical Officer (laboratory)—A. Proctor.

At Melbourne—
Principal Research Officer—S. Fowler.
Research Officer (biologist)—M. Blackburn, M.Sc.

At Perth—
Senior Research Officer (biologist)—D. L. Serventy, B.Sc., Ph.D.
Research Officer (biologist)—J. M. Thomson, M.Sc.
Research Officer (chemist and hydrologist)—R. S. Spencer, B.Sc.
Technical Officer—K. Sheard.
Technical Officer (seagoing)—B. Shipway.

At Hobart—
Research Officer (biologist)—A. M. Olsen, M.Sc.

12. Australian National Standards Laboratory.*

Clerical—
Chief Clerk—R. F. Williams.

Drawing Office—
Chief Draughtsman—C. Williamson.

Library—
Librarian—Miss M. Barnard, B.A.
Librarian—Miss B. V. Mortlock, B.A.
Librarian—Miss M. McKechnie, B. A.
Assistant Librarian—Miss E. Andrews, B.A.
Assistant Librarian—Miss F. J. Humphreys, B.A.
Assistant Librarian—Miss J. M. Cook.

Workshops—
Works Supervisor—J. Hanna.

13. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—N. A. Esserman, B.Sc.
Technical Secretary—D. F. Perkins, B.E.
Senior Research Officer—P. M. Gilet, B.Sc., B.E.
Research Officer—G. A. Bell, B.Sc.
Research Officer—C. F. Bruce, M.Sc.
Research Officer—J. A. Macinante, B.E., A.S.T.C.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—R. H. Furniss, A.S.T.C.
Research Officer—Miss M. C. Dive, B.Sc.
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—W. A. F. Cuninghame, B.E.
Research Officer—Mrs. P. M. Aitchison, B.Sc.
Research Officer—P. V. Moran, B.E.
Research Officer—Miss I. E. Dewhurst, B.Sc., B.Ed.
Research Officer—R. J. Ellis, B.E.
Research Officer—J. Waldersee, B.Sc.
Research Officer—Miss C. M. Guilfoyle, B.Sc.
Research Officer—Miss M. M. Douglas, B.Sc.
Research Officer—Miss P. M. Yelland.
Technical Officer—D. H. Fox.
Technical Officer—W. Dollar, A.S.T.C.
Technical Officer—Miss B. Munro.
Technical Officer—Mrs. N. Maloney.
Technical Officer—O. Pain.

* The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory.

14. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—D. M. Myers, B.Sc., D.Sc.Eng.
Technical Secretary (seconded)—L. G. Dobbie, M.E.
Technical Secretary (acting)—R. C. Richardson, B.E.
Senior Research Officer—W. K. Clothier, B.Sc., M.E.
Senior Research Officer—W. R. Blunden, B.Sc., B.E.
Research Officer—A. M. Thompson, B.Sc.
Research Officer—R. J. Meakins, B.Sc., Ph.D., D.I.C. (seconded from Division of Industrial Chemistry).
Research Officer—B. V. Hamon, B.Sc., B.E.
Research Officer—A. W. Love, M.A.
Research Officer—D. J. Cole, B.E.E.
Research Officer—D. L. Hollway, B.E.E., M.Eng.Sc.
Research Officer—L. Medina, Dipl. Ing.
Research Officer—R. K. Oliver, B.E.
Research Officer—G. A. Day.
Research Officer—J. S. Dryden, M.Sc. (abroad).
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—N. A. Gibson, M.Sc. (seconded from Division of Industrial Chemistry).
Research Officer—H. W. Stokes, B.Ec.
Technical Officer—R. W. Archer.
Technical Officer—F. C. Brown.
Technical Officer—R. J. Keith.

15. Division of Physics.

(Head-quarters: National Standards Laboratory at University of Sydney).

Administration—
Chief—G. H. Briggs, D.Sc., Ph.D.
Acting Chief—A. F. A. Harper, M.Sc.
Technical Secretary—D. S. Woodward.

Heat—
Senior Research Officer—A. F. A. Harper, M.Sc.
Research Officer—W. R. G. Kemp, B.Sc.
Research Officer—R. G. Wylie, B.Sc.
Research Officer—W. A. Caw, B.Sc.
Research Officer—Miss R. Scott, B.Sc.
Technical Officer—J. H. Bestford, B.Sc.

Light—
Senior Research Officer—R. G. Giovanelli, M.Sc.
Research Officer—H. F. Pollard, M.Sc. (part-time).
Research Officer—J. W. Pearce, B.Sc.
Research Officer—W. H. Steel, B.A., B.Sc.
Research Officer—G. H. Godfrey, M.A., B.Sc. (part-time).
Research Officer—J. E. Zimmerman, B.Sc.
Technical Officer—V. R. Schaefer.

Solar Physics—
Senior Research Officer—R. G. Giovanelli, M.Sc.
Research Officer—J. K. Mackenzie, B.A., B.Sc.

Physics of Solids—
Research Officer—N. A. Faull, B.Sc.

Wool Research—
Research Officer—E. H. Mercer, B.Sc. (abroad).
Research Officer—Mrs. K. R. Makinson, B.A.

Atomic Physics—
Research Officer—W. I. B. Smith, B.Sc. (abroad).

Electrical Standards—
Research Officer—N. A. Faull, B.Sc.

Technical Services—
Technical Officer—J. E. Thompson.

16. Division of Aeronautics.

(Head-quarters: Lorimer-street, Fisherman's Bend, Melbourne; Postal Address: Box 4331, G.P.O., Melbourne.)

Administration—
Chief—L. P. Coombes, D.F.C., B.Sc. (Eng.).
Secretary—F. M. McDonough, B.C.E.
Clerk—V. H. Leonard.

Structures and Materials Section—
Senior Principal Research Officer—H. A. Wills, B.E.
Senior Research Officer—F. S. Shaw, B.E. (abroad).
Research Officer—W. W. Johnstone, M.E.
Research Officer—J. Solvey, B.Sc., B.Ae.E.
Research Officer—F. H. Hooke, B.Sc., B.E.
Research Officer—F. W. Hooton, B.Sc., B.E.
Research Officer—R. C. T. Smith, M.A., B.Sc. (abroad).
Research Officer—J. P. O. Silberstein, B.A. (abroad).
Research Officer—A. O. Payne, B.E.Sc.
Research Officer—R. W. Traill-Nash, B.E. (abroad).
Research Officer—Miss E. H. Mann, B.A. (abroad).
Research Officer—N. B. Joyce, B.E.
Research Officer—Miss D. A. Lemaire, B.Mech.E.
Research Officer—M. S. Paterson, B.E. (abroad).
Research Officer—L. H. Mitchell, B.E.
Research Officer—W. Freiberger, B.A.
Research Officer—J. R. M. Radock, B.A.
Technical Officer—N. E. Richards.
Technical Officer—J. H. Straw.
Technical Officer—C. M. Bailey.
Technical Officer—G. W. Wycherley.
Technical Officer—C. A. Patching.
Technical Officer—J. Y. Mann.
Technical Officer—J. G. King.

Metallurgy Section—
Senior Research Officer—J. B. Dance, B.Met.E.
Adviser on Corrosion—P. F. Thompson.
Research Officer—A. R. Edwards, B.Met.E.
Research Officer—H. L. Wain, B.Met.E.
Research Officer—H. T. Greenaway, B.Met.E.
Research Officer—E. J. T. Lumley.
Research Officer—C. J. Osborn, B.Met.E.
Research Officer—N. A. McKinnon, M.Sc.
Research Officer—F. G. Lewis, B.Sc.
Research Officer—N. F. Dewsnap, B.Met.E.
Research Officer—W. R. Flower, B.Sc.
Technical Officer—K. R. Hanna.
Technical Officer—H. Bellamy.
Technical Officer—L. M. Bland.
Technical Officer—S. T. M. Johnstone.
Technical Officer—F. D. Rowe.

Aerodynamics Section—
Acting Officer-in-charge—R. A. Shaw, M.A. (on loan from Ministry of Supply, London).
Senior Research Officer—J. R. Green, D.Phil., B.E.
Research Officer—G. K. Batchelor, M.Sc. (abroad).
Research Officer—R. W. Cumming, B.E.
Research Officer—J. F. M. Scholes, B.Eng.Sc., B.E.
Research Officer—J. B. Willis, M.Sc.
Research Officer—A. F. Pillow, B.A. (abroad).
Research Officer—*J. M. Evans, B.E.
Research Officer—E. R. Johnson, M.Sc.
Research Officer—D. C. Collis, B.Sc.
Research Officer—A. N. W. McCleave, B.E.
Research Officer—F. Redlich, B.E.
Research Officer—J. K. Strachan, B.A., B.Sc.
Research Officer—R. H. Adair, B.E.
Research Officer—Mrs. B. L. Cumming, M.A. (part-time).
Research Officer—H. C. Levey, B.Sc. (part-time).
Technical Officer—L. T. Watson.
Technical Officer—*V. J. Smith.
Technical Officer—R. A. Wallis.
Technical Officer—G. F. Gerrand.
Technical Officer—A. F. W. Langford.
Technical Officer—J. D. Belot.

Engines and Fuel Section—
Principal Research Officer—M. W. Woods, D.Phil., B.E., B.Sc.
Senior Research Officer—T. S. Keeble, B.E., B.Sc.

* Attached to Department of Aeronautical Engineering, Sydney University.

Senior Research Officer—W. B. Kennedy, B.Mech.E.
Research Officer—F. G. Blight, B.Sc., B.E.
Research Officer—J. C. Wisdom, B.Mech.E. (abroad).
Research Officer—D. W. Lees, B.Mech.E.
Research Officer—R. E. Pavia, M.Eng.Sc., B.Mech.E.
Research Officer—R. A. Wright, B.Mech.E.
Research Officer—R. V. Pavia, B.Mech.E.
Research Officer—R. L. Brooks, B.Sc.Eng.
Research Officer—A. L. Deans, B.Mech.E.
Research Officer—A. E. Billington, B.Sc.
Research Officer—W. Howard, B.E. (Aero.).
Research Officer—A. G. Thompson, B.E.
Technical Officer—D. Pescod.
Technical Officer—V. J. McGoldrick.
Technical Officer—H. J. F. Gerrand.
Technical Officer—L. J. Berry.
Technical Officer—M. L. Atkin.

Instruments Section—
Senior Research Officer—A. A. Townsend, M.Sc. (abroad).
Research Officer—H. I. Pizer, B.E.E.
Research Officer—R. C. H. Bravington, B.Sc.
Technical Officer—A. N. A. Clowes.

Applied Research Section—
Senior Research Officer—B. McA. Foster, B.C.E., D.I.C.

Workshops—
Workshops Supervisor—D. W. Eaton.

Drawing Office—
Sectional Draughtsman—J. M. Morgan.

Photography—
Technical Officer—Miss E. F. Lightfoot.

Library—
Librarian—Miss H. P. Meggs.
Librarian—Miss B. M. Brown.

17. Division of Industrial Chemistry.

(Head-quarters: Lorimer-street, Fisherman's Bend, Melbourne; Postal Address: Box 4331, G.P.O., Melbourne.)

Administration—
Chief—I. W. Wark, D.Sc., Ph.D.
Divisional Secretary—L. Lewis, B.Met.E. (acting leader of Chemical Engineering Section).
Assistant Secretary—A. E. Scott, M.Sc. (acting Secretary).

Minerals Utilization Section—
Principal Research Officer—R. G. Thomas, B.Sc.
Senior Research Officer—A. Walkley, B.A., B.Sc., Ph.D.
Senior Research Officer—A. W. Wylie, M.Sc., Ph.D.
Research Officer—P. Dixon, M.Sc.
Research Officer—F. K. McTaggart, M.Sc.
Research Officer—T. R. Scott, M.Sc., B.Ed.
Research Officer—F. R. Hartley, M.Sc.
Research Officer—A. D. Wadsley, M.Sc.
Research Officer—I. C. Kraitzer.
Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—R. C. Croft, B.Sc.
Technical Officer—H. R. Skewes.
Technical Officer—J. F. Moresby, A.M.T.C.

Cement and Ceramics Section—
Principal Research Officer—A. R. Alderman, D.Sc., Ph.D.
Research Officer—A. J. Gaskin, M.Sc. (part-time).
Research Officer—R. H. Jones, B.Sc. (Hons.).
Research Officer—H. E. Vivian, B.Sc.Agr.
Research Officer—E. R. Segnit, M.Sc.
Research Officer—C. E. S. Davis, B.Sc. (Hons.).
Research Officer—H. R. Samson, M.Sc.
Technical Officer—J. Coutts, A.M.T.C.

Foundry Sands Section—
Research Officer—H. A. Stephens, B.Sc. (Hons.).
Technical Officer—G. V. Cullen.

Physical Chemistry Section—
Research Officer—K. L. Sutherland, M.Sc.
Research Officer—W. E. Ewers, M.Sc.
Research Officer—A. G. Dobson, M.Sc.
Research Officer—W. W. Mansfield, B.Sc. (Hons.).
Technical Officer—L. F. Evans, D.S.M.B.
Technical Officer—J. A. Corbett.
Technical Officer—H. F. A. Hergt, A.M.T.C.

Chemical Physics Section—
Principal Research Officer—A. L. G. Rees, M.Sc., Ph.D.
Research Officer—A. Walsh, M.Sc.
Research Officer—J. L. Farrant, M.Sc.
Research Officer—M. S. Walker, B.E.
Research Officer—J. M. Cowley, M.Sc.
Research Officer—G. R. Hercus, B.Sc.
Research Officer—A. J. Hodge, B.Sc. (Hons.).
Research Officer—B. G. Green, B.Sc. (Hons.).

Organic Section—
Principal Research Officer—H. H. Hatt, B.Sc., Ph.D. (abroad).
Senior Research Officer—J. R. Price, M.Sc., D.Phil.
Research Officer—J. S. Fitzgerald, M.Sc., Ph.D. (abroad).
Research Officer—M. E. Winfield, M.Sc., Ph.D.
Research Officer—K. E. Murray, B.Sc. (Hons.).
Research Officer—N. C. Hancox, M.Sc.
Research Officer—R. G. Curtis, M.Sc. (abroad).
Research Officer—R. J. L. Martin, M.Sc. (on study leave).
Research Officer—D. J. Clark, M.Sc.
Research Officer—L. K. Dalton, D.S.T.C.
Research Officer—R. B. Bradbury, B.Agr.Sc., D.Bendigo S.M.
Research Officer—W. D. Crow, B.Sc. (Hons.).
Technical Officer—W. J. Troyahn, A.M.T.C. (on study leave).
Technical Officer—W. E. Hillis, A.G.Inst.Tech. (on study leave).
Technical Officer—Miss F. M. Jensen, A.M.T.C.

Biochemistry Section—
Senior Research Officer—F. G. Lennox, D.Sc. (abroad).
Research Officer—W. J. Ellis, A.S.T.C.
Research Officer—W. G. Crewther, M.Sc.
Research Officer—Miss M. E. Maxwell, M.Sc.
Research Officer—J. M. Gillespie, M.Sc.

Chemical Engineering Section—
Senior Research Officer—D. R. Zeidler, M.Sc. (abroad).
Research Officer—I. Brown, B.Sc. (Hons.).
Research Officer—R. W. Urie, B.Sc. (on study leave).
Research Officer—J. F. Pearse, B.Sc. (Hons.) (on study leave).
Research Officer—B. W. Wilson, M.Sc.
Technical Officer—J. L. Clay, A.M.T.C.
Technical Officer—D. H. Trethewey, A.M.T.C.
Technical Officer—K. A. Ophel.
Senior Draughtsman—C. Simpson.
Draughtsman—L. R. Bull.
Draughtsman—M. B. Blackwell.

At University of Western Australia—Alunite Investigations—
Research Officer—G. H. Payne, M.Sc.
Research Officer—R. H. Lee, B.Sc. (Hons.).

At Canberra, Division of Economic Entomology—
Research Officer—R. H. Hackman, M.Sc. (on study leave).

At Sydney, Division of Electrotechnology—
Research Officer—R. H. Meakins, B.Sc., Ph.D.
Research Officer—N. A. Gibson, M.Sc.

Library—
Librarian—Miss H. P. Meggs (part-time).
Librarian—Miss B. M. Brown, B.Sc. (part-time).

18. Division of Radiophysics.

(Head-quarters: at University of Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.
Technical Secretary—A. J. Higgs, B.Sc.

Research—
Principal Research Officer—J. L. Pawsey, M.Sc., Ph.D.

Solar Noise—
Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Senior Research Officer—L. L. McCready, B.Sc., B.E.
Research Officer—H. C. Minnett, B.Sc., B.E.
Research Officer——Miss R. Payne Scott, M.Sc.
Research Officer—S. F. Smerd, B.Sc.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer, J. G. Bolton, B.A.
Technical Officer—K. R. McAlister.
Technical Officer—J. V. Hindman.
Technical Officer—G. J. Stanley, A.S.T.C.

Middle Atmosphere—
Research Officer—F. J. Kerr, M.Sc.
Research Officer—C. A. Shain, B.Sc.
Technical Officer—C. S. Higgins.

Ionosphere—
Principal Research Officer—G. H. Munro, M.Sc.
Technical Officer—O. C. Turner.

Radar Meteorology—
Senior Research Officer.—E. B. Kraus, Ph.D.
Senior Research Officer—P. Squires, M.A.
Research Officer—G. J. Parker, B.Sc., B.E.
Research Officer—N. R. Labrum, B.Sc.
Research Officer—Miss B. Lippman, B.Sc.

Mathematical Physics—
Research Officer—T. Pearcey, B.Sc.
Research Officer—K. C. Westfold, M.A., B.Sc.
Research Officer—Miss M. A. Adamson, B.A., Dip.Ed.
Research Officer—Miss H. Taylor, B.A., Dip.Ed.

Measurements and Standards—
Senior Research Officer—F. J. Lehany, M.Sc.
Research Officer—J. P. Wild, B.A.

Vacuum Physics—
Research Officer—B. Y. Mills, B.Sc., B.E.
Research Officer—T. R. Kaiser, M.Sc.
Technical Officer—F. C. James.
Technical Officer—R. Lorimer.

Development—
Senior Research Officer—V. D. Burgmann, B.Sc., B.E.

Civil Aviation—Air—
Research Officer—M. Beard, B.Sc., B.E.
Research Officer—J. G. Downes, B.Sc.
Research Officer—E. B. Mulholland, B.Sc., B.E.

Civil Aviation—Ground—
Research Officer—H. N. Edwards, B.Sc., B.E.
Research Officer—R. B. Coulson, B.Sc., B.E.
Technical Officer—G. A. Wells.
Technical Officer—P. T. Hedges.
Technical Officer—T. D. Newnham.
Technical Officer—J. Algie.

Radio Control and Telemetering—
Senior Technical Officer—G. T. Miles.

Survey—
Research Officer—J. Warner, B.Sc., B.E.
Research Officer—A. B. Thomas, B.A.
Research Officer—H. L. Humphries, B.Sc., B.E.
Research Officer—F. Gardner, B.Sc., B.E.
Technical Officer—R. C. Baker.
Technical Officer—D. C. Dunn.

Engineering Services—
Works Supervisor—H. Byers.
Chief Draughtsman—F. C. Carter.
Assistant Technical Secretary—J. P. Eagles.

Publications—
Research Officer—Miss L. F. Plunkett, B.Sc., Dip.Ed.

Officers Overseas—
Research Officer—B. F. C. Cooper, B.Sc., B.E.
Research Officer—Miss J. M. Freeman, M.Sc.
Research Officer—R. N. Bracewell, B.Sc., B.E.
Research Officer—J. S. Gooden, B.Sc.
Research Officer—J. L. Symonds, B.Sc.
Technical Officer—K. Sheridan.

19. Section of Tribophysics.

(Head-quarters: at University of Melbourne.)

Officer-in-Charge—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Principal Research Officer—W. Boas, D.Ing., M.Sc.
Research Officer—J. N. Gregory, M.Sc.
Research Officer—R. W. K. Honeycombe, M.Sc.
Research Officer—T. V. Krok, B.E.
Research Officer—M. F. R. Mulcahy, M.Sc., A.G.Inst.Tech. (abroad).
Research Officer—R. G. Vines, M.Sc.
Research Officer—E. B. Greenhill, M.Sc. (abroad).
Research Officer—A. J. W. Moore, B.Sc. (abroad).
Research Officer—E. R. Ballantyne, B.Sc.
Research Officer—M. E. Hargreaves, B.Met.E.
Research Officer—D. Michell, B.E.E.
Research Officer—Miss M. J. Newing, B.Sc.
Research Officer—G. J. Ogilvie, B.Met.E., M.Eng.Sc.
Research Officer—J. V. Sanders, B.Sc. (Hons.).
Research Officer—J. A. Spink, B.Sc.
Research Officer—G. W. West, B.E.E.
Technical Officer—Miss J. Collins.
Technical Officer—H. F. Eggington, A.Sw.T.C.
Technical Officer—F. H. Hay.
Technical Officer—D. S. Kemsley, F.M.T.C.
Technical Officer—R. G. Sherwood, A.M.T.C.

20. Building Materials Research.

(Head-quarters: Graham-road, Highett, Victoria.)

Adminstration—
Officer-in-charge—I. Langlands, B.E.E., M.Mech.E.
Acting Officer-in-charge—J. S. Hosking, M.Sc., Ph.D.
Technical Secretary—W. F. Evans, B.Sc.

Information and Library—
Research Officer—J. R. Barned, B.Sc.
Research Officer—R. C. McTaggart, B.Sc.
Librarian—Miss A. G. Baldwin, B.A.

Mechanical and Physical Testing Laboratory—
Research Officer—P. H. Sulzberger, B.Sc.
Research Officer—A. J. Wilkins, B.E.
Technical Officer—A. R. Ludbrook.
Technical Officer—I. McLachlan.

Concrete Investigations—
Principal Research Officer—A. R. Alderman, D.Sc., Ph.D. (part-time).
Research Officer—W. H. Taylor, M.C.E.

Masonry Investigations—
Senior Research Officer—J. S. Hosking, M.Sc., Ph.D.
Research Officer—H. V. Hueber, Dr. Phil.

Surfacing Materials Investigations—
Senior Research Officer—E. H. Waters, M.Sc.
Research Officer—J. E. Bright, B.Sc.
Research Officer—T. S. Holden, B.Sc.
Building Boards and Insulating Materials—
Research Officer—R. W. Muncey, B.E.E. (Hons.).
Research Officer—P. E. Hands, B.Sc. (Hons.).
Technical Officer—A. W. Wilson.
Technical Officer—J. J. Russell.
Organic Materials Investigations—
Research Officer—B. M. Holmes, M.Sc.
Technical Officer—V. Chew, B.Sc.
Drawing Office—
Draughtsman—G. T. Stephens.

21. Flax Research.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-Charge—W. L. Greenhill, M.E.
Senior Research Officer—Miss J. F. Couchman, B.Sc.
Research Officer—G. W. Lanigan, M.Sc.
Research Officer—A. M. Munro, M.A. (Oxon.).
Research Officer—W. Shepherd, B.Sc., B.Agr.Sc.
Technical Officer—M. Tisdall.

22. Section of Mathematical Statistics.

(Head-quarters: at University of Adelaide.)

At Sectional Head-quarters—
Officer-in-Charge—E. A. Cornish, M.Sc., B.Agr.Sc.
Research Officer—R. Birtwistle, B.Sc.
Research Officer—G. G. Coote, B.A., B.Sc.
Research Officer—G. E. Ferris, B.Sc.
Research Officer—A. T. James, B.Sc. (Hons.).
Sectional Secretary—Miss E. M. G. Goodale.
At Division of Animal Health and Production, Sydney—
Research Officer—Miss H. A. Newton Turner, B.Arch.
Research Officer—Miss V. M. Botham, B.Sc.
At Division of Forest Products, Melbourne—
Research Officer—E. J. Williams, B.Com.
Research Officer—R. T. Leslie, B.A. (Hons.), B.Sc.
At Divisions of Plant Industry and Economic Entomology, Canberra—
Senior Research Officer—G. A. McIntyre, B.Sc., Dip.Ed.

23. Radio Research.

(Head-quarters: c/o Electrical Engineering Department, University of Sydney.)

At Sydney—
Principal Research Officer—G. H. Munro, M.Sc.
Research Officer—L. S. Prior, B.Sc.
Technical Officer—Mrs. M. Harrison, B.Sc.
Technical Officer—G. C. Morrison.
Technical Officer—Miss B. Hardwick, B.A.
Technical Officer—Miss B. A. Longworth, B.A.
Draughtsman—R. de C. Wark.
At Mt. Stromlo, Canberra—
Senior Principal Research Officer—D. F. Martyn, D.Sc., Ph.D.
Research Officer—L. H. Heisler, B.Sc.
Technical Officer—R. O. Errey.

24. Dairy Research Section.

(Head-quarters: Lorimer-street, Fisherman's Bend, Melbourne.)

Officer-in-Charge—G. Loftus Hills, B.Agr.Sc.
Senior Research Officer—E. G. Pont, M.Agr.Sc.
Senior Research Officer—R. C. Hutchinson, D.Sc.
Research Officer—J. Conochie, B.Sc. (Agric.).
Research Officer—A. J. Lawrence, B.Sc.

25. Section of Physical Metallurgy.

(Head-quarters: At University of Melbourne.)

Officer-in-Charge (honorary)—Professor J. N. Greenwood, D.Sc., M.Met.E.
Senior Research Officer—D. W. Davison, B.Sc., Ph.D. (abroad).
Research Officer—H. W. Worner, M.Sc.
Technical Officer—Miss R. I. Shoebridge, B.Sc.

26. Ore-dressing Investigations.

At University of Melbourne—
Officer-in-Charge—H. H. Dunkin, B.Met.E. (part-time).
Senior Research Officer—K. S. Blaskett, B. E.
Technical Officer—F. D. Drews.
At School of Mines, Adelaide, South Australia—
Research Officer—D. R. Blaskett, B.E.
At School of Mines, Kalgoorlie, Western Australia—
Officer-in-Charge—R. A. Hobson, B.Sc. (part-time).

27. Other Investigations.

Mineragraphic Investigations—
Senior Principal Research Officer—F. L. Stillwell, D.Sc.
Senior Research Officer—A. B. Edwards, D.Sc., Ph.D.
Meteorological Physics Research—
Officer-in-Charge—C. H. B. Priestley, M.A.
Textile Technology—
Principal Research Officer—E. J. Drake.
Oenological Research—
Research Officer—J. C. M. Fornachon, M.Sc., B.Agr.Sc.

5. *Publications of the Council.*—The following publications were issued by the Council during the year:—

(i) *Bulletins.*

No. 197.—The Analysis of the Hydrocarbon Gases by Fractional Distillation with Especial Reference to Cracked Tar Gases, by R. J. L. Martin, M.Sc.

No. 198.—Plant Responses to Molybdenum as a Fertilizer. 1. Molybdenum and Symbiotic Nitrogen Fixation, by A. J. Anderson, B.Sc. (Agric.), and Margaret P. Thomas, B.Sc. 2. Factors Affecting the Response of Plants to Molybdenum, by A. J. Anderson, B.Sc. (Agric.), and A. C. Oertel, M.Sc.

No. 199.—The Use of Mineral Dusts for the Control of Wheat Pests, by Frank Wilson.

No. 200.—Preparation of Core Ingredients for Searchlight Carbons, by T. R. Scott, M.Sc., B.Ed.

No. 201.—Grazing Management: Continuous and Rotational Grazing by Merino Sheep. 1. Study of the Production of a Sown Pasture in the Australian Capital Territory under Three Systems of Grazing Management, by R. M. Moore, B.Sc.Agr., Nancy Barrie, B.Sc.Agr., and E. H. Kipps, B.Sc. Appendix, The Measurement of Pasture Yield under Grazing, by G. A. McIntyre, B.Sc. 2. The Effect of Continuous and Rotational Grazing on the Infestation of Sheep with Internal Parasites, by H. McL. Gordon, B.V.Sc., and Helen Newton Turner, B.Arch. 3. Note on Pasture Management, by J. Griffiths Davies, B.Sc., Ph.D.

No. 202.—The Strain Complex and Symptom Variability of Tomato Spotted Wilt Virus, by D. O. Norris, M.Sc. (Agric.).

No. 203.—Agar in Australia, by E. J. Ferguson Wood, B.A., M.Sc.

No. 204.—A Soil Survey of Part of Waterhouse Estate, County of Dorset, North-East Coast, Tasmania, by G. D. Hubble, B.Agr.Sc.

No. 205.—Studies on the Breeding Performance of Ewes, by R. B. Kelley, D.V.Sc.

No. 206.—Pedogenesis Following the Dissection of Lateritic Regions in Southern Australia, by C. G. Stephens, M.Sc.

No. 207.—The Fumigation of Wheat in Bag Stacks, by Frank Wilson and F. J. Gay, B.Sc., D.I.C.

No. 208.—Surface Fumigation of Insect Infestations in Bulk-Wheat Depots, by Frank Wilson and A. T. Mills.

No. 209.—Interaction of Insect Infestation, Temperature, and Moisture Content in Bulk-Depot Wheat, by Frank Wilson.

No. 211.—The Water Retting of Flax, by W. L. Greenhill, M.E., Dip.Sc., and Jean F. Couchman, B.Sc.

No. 217.—The Relative Importance of Live Sheep and of Carrion as Breeding Grounds for the Australian Sheep Blowfly *Lucilia cuprina*, by D. F. Waterhouse, M.Sc.

No. 218.—Studies of the Physiology and Toxicology of Blowflies. 12. The Toxicity of DDT as a Contact and Stomach Poison for Larvae of *Lucilia cuprina*. 13. Insectary Tests of Repellents for the Australian Sheep Blowfly, by D. F. Waterhouse, M.Sc.

No. 224.—Mechanical Composition of Soil in Relation to Field Descriptions of Texture, by T. J. Marshall, M.Ag.Sc., Ph.D.

(ii) *Quarterly Journal.*

Vol. 19, No. 3, August, 1946.
Vol. 19, No. 4, November, 1946.
Vol. 20, No. 1, February, 1947.
Vol. 20, No. 2, May, 1947.

(iii) *Annual Report for the year ending 30th June*, 1946.

(iv) *Miscellaneous.*

"The Commercial Timbers of Australia—Their Properties and Uses", by I. H. Boas, M.Sc.

XXIII. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Council desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Council also wishes to acknowledge the assistance it has received from its State Committees and other Committees, the members of which have placed their knowledge and experience so freely at its disposal.

DAVID RIVETT, Chairman.
A. E. V. RICHARDSON
F. W. G. WHITE
I. CLUNIES ROSS
D. A. MOUNTJOY
} Executive Committee.

G. A. COOK, Secretary.
11th November, 1947.

APPENDIX.

PERSONNEL OF THE COUNCIL AND COMMITTEES ADVISING ON THE COUNCIL'S OWN WORK OR ON CO-OPERATIVE WORK IN WHICH THE COUNCIL IS ASSISTING.

COUNCIL (AS AT 30TH JUNE, 1947).

Executive.

Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S. (Chairman).
A. E. V. Richardson, C.M.G., M.A., D.Sc. (Chief Executive Officer).
F. W. G. White, M.Sc., Ph.D.
I. Clunies Ross, D.V.Sc.
D. A. Mountjoy.

Chairmen of State Committees.

A. J. Gibson, M.E. (New South Wales).
Professor E. J. Hartung, D.Sc. (Victoria).
R. J. Donaldson, D.S.O., B.C.E. (Queensland).
Professor Sir Kerr Grant, M.Sc. (South Australia).
P. H. Harper, B.A. (Western Australia).
F. H. Foster, B.C.E. (Tasmania).

Co-opted Members.

N. K. S. Brodribb, C.B.E., F.R.I.C.
Sir Harry Brown, C.M.G., M.B.E.
Professor W. J. Dakin, D.Sc.
M. T. W. Eady.
W. S. Kelly.
E. H. B. Lefroy.
G. Lightfoot, M.A.
Professor Sir John Madsen, B.E., D.Sc.
J. P. Tivey, B.A., B.Sc., B.E.
Professor S. M. Wadham, M.A., Dip.Agr.

STATE COMMITTEES (AS AT 30TH JUNE, 1947).

New South Wales.

A. J. Gibson, M. E. (*Chairman*).
Professor Sir Henry E. Barraclough, K.B.E., V.D., B.E., M.M.E.
J. N. Briton, B.Sc., B.E.
Sir Harry Brown, C.M.G., M.B.E.
Professor W. J. Dakin, D.Sc.
Professor J. C. Earl, D.Sc., Ph.D., F.R.I.C.
W. R. Hebblewhite, B.E.
L. J. Jones.
Hon. Sir Norman W. Kater, M.B., Ch.M., M.L.C.
Sir Frederick McMaster.
Professor Sir John Madsen, B.E., D.Sc.
J. Merrett.
R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
R. G. C. Parry Okeden.
J. G. Peake.
A. R. Penfold, F.R.I.C.
Professor J. D. Stewart, F.R.C.V.S., B.V.Sc.
E. H. F. Swain, Dip.For.
J. P. Tivey, B.A., B.Sc., B.E.
W. L. Waterhouse, M.C., D.Sc.Agr., D.I.C.
Emeritus-Professor R. D. Watt, M.A., B.Sc.
C. M. Williams.

Victoria.

Professor E. J. Hartung, D.Sc. (*Chairman*).
R. S. Andrews, B.Sc.
W. Baragwanath.
N. K. S. Brodribb, C.B.E., F.R.I.C.,
Professor F. M. Burnet, M.D., Ph.D., F.R.S.
M. T. W. Eady.
Sir Herbert W. Gepp.
Professor J. N. Greenwood, D.Sc., M.Met.E.
Russell Grimwade, C.B.E., B.Sc.
H. Herman, D.Sc., M.M.E., B.C.E.
Sir Dalziel Kelly, LL.B.
G. Lightfoot, M.A.
H. A. Mullett, B.Agr.Sc.
N. Taylor, B.Sc., F.R.I.C.
Professor J. S. Turner, M.A., M.Sc., Ph.D.
Professor S. M. Wadham, M.A., Dip.Agr.
W. E. Wainwright, A.S.A.S.M.
L. J. Weatherly, M.A.
Professor H. A. Woodruff, B.Sc., L.R.C.P., M.R.C.S., M.R.C.V.S.

SOUTH AUSTRALIA.

Professor Sir Kerr Grant, M.Sc. (*Chairman*).
A. J. Allen.
A. R. Callaghan, B.Sc., B.Sc.Agr., D.Phil.
S. B. Dickinson, M.Sc.
J. H. Gosse.
C. Haselgrove.
Professor T. H. Johnston, M.A., D.Sc.
W. S. Kelly.
H. R. Marston.
Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
Professor M. L. Mitchell, M.Sc.
F. W. Moorhouse, M.Sc.
F. T. Perry.
Professor J. A. Prescott, D.Sc.
S. D. Shield, A.S.A.S.M.
W. J. Spafford, R.D.A.
L. K. Ward, B.A., B.E., D.Sc.
Professor J. G. Wood, D.Sc., Ph.D.

QUEENSLAND.

R. J. Donaldson, D.S.O., B.C.E. (*Chairman*).
Professor H. Alcock, M.A.
A. F. Bell, M.Sc., D.I.C.
S. F. Cochran.
Professor E. J. Goddard, B.A., D.Sc.
V. Grenning.
J. B. Henderson, O.B.E., F.R.I.C.
Professor T. G. H. Jones, D.Sc.
Professor D. H. K. Lee, M.Sc., M.D.
J. McCann.
A. McCulloch, M.E.
W. M. McLean.
J. F. Meynink.
P. B. Newcomen.
Professor T. Parnell, M.A.
C. R. Paterson, B.E.
R. P. M. Short.
H. C. Urquhart, M.Sc.
R. Veitch, B.Sc.Agr., B.Sc.For.
J. L. Wilson.
C. E. Young, D.S.O.

WESTERN AUSTRALIA.

P. H. Harper, B.A. (*Chairman*).
G. K. Baron-Hay, M.C., B.Sc. (Agric.).
Professor N. S. Bayliss, B.A., B.Sc., Ph.D.
H. Bowley.
F. G. Brinsden
W. G. Burges.
Professor E. deCourcy Clarke, M.A.
Professor G. A. Currie, D.Sc., B.Agr.Sc.
A. L. B. Lefroy.
E. H. B. Lefroy.
B. Meecham.
Professor G. E. Nicholls, D.Sc.
L. W. Phillips, M.Sc., M.Ed.
Professor A. D. Ross, M.A., D.Sc.
T. N. Stoate, M.Sc., Dip.For.
G. L. Sutton, D.Sc.Agr.
Professor E. J. Underwood, B.Sc.(Agric.), Ph.D.
R. B. Williamson.

TASMANIA.

F. H. Foster, B.C.E. (*Chairman*).
L. R. S. Benjamin.
N. P. Booth, F.R.I.C.
Professor A. Burn, M.Sc., B.E.
F. W. Hicks.
S. L. Kessell, M.Sc., Dip.For.
A. W. Knight, B.Sc., M.E., B.Com.
Professor A. L. McAulay, M.A., B.Sc., Ph.D.
D. O. Meredith
F. H. Peacock.
F. B. Richardson, M.A.
Hon. Sir Rupert Shoobridge, M.L.C.
H. B. Somerset, M.Sc.
S. W. Steane, B.A.

COMMONWEALTH RESEARCH STATION, MERBEIN—CONSULTATIVE COMMITTEE.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R. (*Chairman*).
Professor J. A. Prescott, D.Sc., Waite Agricultural Research Institute, University of Adelaide.
P. Malloch, Commonwealth Dried Fruits Control Board.
E. J. Casey, Commonwealth Dried Fruits Control Board.
A. E. Cameron, representing Advisory Committee.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein (*Secretary*).

IRRIGATION RESEARCH STATION, GRIFFITH—CONSULTATIVE COMMITTEE.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R. (*Chairman*).
Professor J. A. Prescott, D.Sc., Waite Agricultural Research Institute, University of Adelaide.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
V. C. Williams, representing Advisory Committee.
E. S. West, B.Sc., M.S., Irrigation Research Station, Griffith (*Secretary*).

COMMONWEALTH RESEARCH STATION, MERBEIN—ADVISORY COMMITTEE.

A. E. Cameron, Red Cliffs Settlement (*Chairman*).
J. A. Aird, B.Sc., B.Agr.Sc., Dip.Com., State Rivers and Water Supply Commission, Victoria.
L. W. Andrew, Waikerie, South Australia.
P. T. Byrnes, Woorinen, Victoria.
E. J. Casey, representing Consultative Committee.
D. W. Cockcroft, Nyah-Woorinen Enquiry Committee.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
J. Gordon, Citrus Growers' Association, Merbein.
A. E. Hazel, Dried Fruits Association, Red Cliffs.
W. B. Hawson, First Mildura Irrigation Trust.
S. Heaysman, Coomealla, New South Wales.
W. Heaysman, Cardross Progress Association.
J. A. Lochhead, Mildura Shire Council.
P. Malloch, representing Consultative Committee.
R. C. Polkinghorne, Nyah-Woorinen Enquiry Committee.
A. Rawlings, Merbein, Victoria.
C. G. Savage, Department of Agriculture, New South Wales.
J. L. Showell, Renmark Irrigation Trust.
R. Stevens, Nyah-Woorinen Enquiry Committee.
A. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia.
S. P. Taylor, Curlwaa, New South Wales.
O. Weste, Renmark, South Australia.
D. C. Winterbottom, Mildura Packers' Association.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein (*Secretary*).

IRRIGATION RESEARCH STATION, GRIFFITH—ADVISORY COMMITTEE.

V. C. Williams, Griffith Producers' Co-op. Ltd. (*Chairman*).
C. G. Savage, R. G. Kebby } Department of Agriculture, New South Wales.
E. R. Iredale, C. T. Lasscock } Rural Bank of New South Wales.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
T. T. Morley, Griffith Producers' Co-op. Co. Ltd.
O. J. Longhurst, A. B. C. Wood } Yenda Producers' Co-op. Society Ltd.
J. H. Alexander, W. Jacka } Leeton Fruitgrowers' Co-op. Society Ltd.
A. G. Enticknap, M.L.A., H. J. Williams } Leeton Co-op. Cannery Ltd.
L. B. Marchant, W. S. Jones } M.I.A. Vegetable Growers' Association.
A. G. Kubank, M.I.A. pastoral interests.
E. S. West, B.Sc., M.S., R. R. Pennefather, B.Agr.Sc. } Irrigation Research Station, Griffith.

DENILIQUIN RESEARCH STATION—TECHNICAL COMMITTEE.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R.
Professor J. A. Prescott, D.Sc., Division of Soils, C.S.I.R.
L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.
H. R. Marston, Division of Biochemistry and General Nutrition, C.S.I.R.
J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.
T. J. Marshall, M.Ag.Sc., Ph.D., Division of Soils, C.S.I.R.
A. J. Vasey, B.Agr.Sc., Division of Animal Health and Production, C.S.I.R.
R. R. Pennefather, B.Agr.Sc., Irrigation Research Station, Griffith.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein.
O. McL. Falkiner, Boonoke Station, Conargo.
J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.
R. W. Prunster, B.Sc. (Agric.), Division of Plant Industry, C.S.I.R. (*Secretary*).

VEGETABLE PROBLEMS COMMITTEE.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R. (*Chairman*).
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein, Victoria.
E. S. West, B.Sc., M.S., Irrigation Research Station, Griffith, New South Wales.
K. Spencer, B.Sc.Agr., Irrigation Research Station, Griffith, New South Wales.
L. J. Lynch, B.Agr.Sc., Division of Food Preservation and Transport, C.S.I.R.
E. M. Hutton, B.Ag.Sc., M.Sc., Division of Plant Industry, C.S.I.R. (*Secretary*).

DRIED FRUITS PROCESSING COMMITTEE.

C. G. Savage, Department of Agriculture, New South Wales (*Chairman*).
W. R. Jewell, M.Sc., B.Met., F.R.I.C., Department of Agriculture, Victoria.
W. M. Carne, Department of Commerce and Agriculture, Melbourne.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein.
A. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia.
E. C. Orton, B.Sc., Commonwealth Research Station, Merbein.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.
D. G. Quinn, Department of Agriculture, Victoria.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R. (*Secretary*).

FLAX RESEARCH ADVISORY COMMITTEE.

J. A. Stevenson, Flax Production Committee (*Chairman*).
I. H. Boas, M.Sc., Melbourne.
R. B. Hogg, representing the Australian flax spinners.
A'b. Weigall, representing the growers.

FISHERIES ADVISORY COMMITTEE.

Professor W. J. Dakin, D.Sc., Department of Zoology, University of Sydney (*Chairman*).
T. C. Roughley, B.Sc., Chief Secretary's Department, New South Wales.
H. Thompson, M.A., D.Sc., Division of Fisheries, C.S.I.R.

ADVISORY COMMITTEE ON RED-LEGGED EARTH MITE INVESTIGATIONS, WESTERN AUSTRALIA.

E. H. B. Lefroy (*Chairman*).
C. F. Jenkins, B.A., Department of Agriculture, Western Australia.
Professor G. A. Currie, B.Agr.Sc., D.Sc., University of Western Australia.
I. Thomas, Department of Agriculture, Western Australia.
A. J. Nicholson, D.Sc., Division of Economic Entomology, C.S.I.R.
L. W. Phillips, M.Sc., M.Ed. (*Secretary*).

VETERINARY ENTOMOLOGICAL COMMITTEE.

(*Formerly the Interdivisional Blowfly Committee; its function is to co-ordinate certain activities of the Divisions of Economic Entomology and of Animal Health and Production.*)

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.
A. J. Nicholson, D.Sc., Division of Economic Entomology, C.S.I.R.
A. W. Turner, O.B.E., D.Sc., D.V.Sc., Division of Animal Health and Production, C.S.I.R.
D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R. (*Secretary*).

NEW SOUTH WALES MEAT RESEARCH ADVISORY COMMITTEE.

L. J. Ashcroft, Liverpool, New South Wales.
E. J. Bowater, Messrs. Angliss and Co. Pty. Ltd., Sydney.
J. M. Davidson, Commonwealth Veterinary Officer, Sydney, representing the Department of Commerce.
J. Merrett, Metropolitan Meat Industry Commissioner, Sydney.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.

MINERAGRAPHIC COMMITTEE.

Emeritus-Professor E. W. Skeats, D.Sc., Melbourne.
W. E. Wainwright, A.S.A.S.M., Australasian Institute of Mining and Metallurgy.

RADIO RESEARCH BOARD.

Professor Sir John Madsen, B.E., D.Sc., University of Sydney (*Chairman*).
Commander N. A. MacKinnon, Director of Naval Communications, R.A.N.
Colonel A. D. Molloy, Director of Signals, A.M.F.
Wing-Cdr. J. W. Reddrop, Director of Telecommunications and Radar, R.A.A.F.
R. v.d. R. Woolley, M.A., M.Sc., Ph.D., Mt. Stromlo Observatory.
Professor T. Parnell, M.A., University of Queensland.
E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.
F. G. Nicholls, M.Sc., C.S.I.R. (*Secretary*).

ELECTRICAL RESEARCH BOARD.

Professor Sir John Madsen, B.E., D.Sc., University of Sydney (*Chairman*).
R. Liddelow, Electricity Supply Association of Australia.
V. J. F. Brain, Electricity Supply Association of Australia.
D. M. Myers, B.Sc., D.Sc.Eng., Division of Electrotechnology, C.S.I.R.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.
F. G. Nicholls, M.Sc., C.S.I.R. (*Conjoint Secretary*).
R. C. Richardson, B.E., Division of Electrotechnology, C.S.I.R. (*Conjoint Secretary*).

BUILDING MATERIALS RESEARCH ADVISORY COMMITTEE.

T. J. Cavanagh, Sydney (*Chairman*).
D. V. Isaacs, M.C.E., Experimental Building Station, Department of Post-war Reconstruction.
A. C. Leith, M.C.E., Melbourne.
G. E. Junck, Melbourne.
H. W. Knight, Sydney.
L. J. Price, M.C., M.E., Department of Works and Housing, Melbourne.
O. McCutcheon, Dip.Arch, Melbourne.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.
I. Langlands, B.E.E., M.Mech.E., Building Materials Research, C.S.I.R.
G. B. Gresford, B.Sc., C.S.I.R. (*Secretary*).

CATALOGUE OF SCIENTIFIC AND TECHNICAL PERIODICALS—EDITORIAL COMMITTEE.

Leigh Scott, M.A., Librarian, University of Melbourne.
John Metcalfe, B.A., Principal Librarian, Public Library of New South Wales.
C. A. McCallum, B.A., Chief Librarian, Public Library, Melbourne.
Ellinor Archer, M.Sc., Chief Librarian, C.S.I.R.

INDUSTRIAL INFORMATION ADVISORY COMMITTEE.

F. H. Campbell, D.Sc., Secondary Industries Division, Department of Post-war Reconstruction.
K. W. Bennett, B.Sc., A.M.T.C., Secondary Industries Division, Ministry of Post-war Reconstruction.
E. A. Goode, M.Sc., Technical Information Section, Munitions Supply Laboratories.
M. I. Homewood, B.Sc., Technical Information Section, Munitions Supply Laboratories.
C. M. Gray, M.Sc., Information Service, C.S.I.R.
F. A. Priest, A.S.A.S.M., Information Service, C.S.I.R. (*Secretary*).

IRRIGATION AND DRAINAGE COMMITTEE FOR SOUTH AUSTRALIA.

C. M. Fowles, Lands Department, South Australia (*Chairman*).
A. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein, Victoria.
A. C. Gordon, Lands Department, South Australia.
H. G. Tolley, Engineering and Water Supply Department, South Australia.

CURLWAA AND COOMEALLA HORTICULTURAL ADVISORY COMMITTEE.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein (*Chairman*).
F. H. Barrett, Water Conservation and Irrigation Commission, New South Wales.
C. T. Lasscock, Rural Bank of New South Wales.
S. Heaysman, representing Coomealla Producers.
J. Bailey, representing Coomealla Producers.
S. P. Taylor, representing Curlwaa Producers.
W. Reeves, representing Curlwaa Producers.
F. S. Oldham, Department of Agriculture, New South Wales (*Secretary*).

WAKOOL LAND-USE COMMITTEE.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein (*Chairman*).
G. B. Gibbs, Water Conservation and Irrigation Commission, New South Wales.
F. I. Bolton, Water Conservation and Irrigation Commission, New South Wales.
F. Matthews, Rural Bank of New South Wales.
M. St.C. McInnes, Rural Bank of New South Wales.
F. Autry-Hall, Department of Agriculture, New South Wales.
B. Savage, Department of Agriculture, New South Wales.
A. Varcoe-Cocks, Wakool Shire Council.
H. J. Robinson, L. Jeffers, W. R. A. Smith, E. E. Toll — representing Wakool District Landowners' Executive.
R. W. Prunster, B.Sc.(Agric.), Council for Scientific and Industrial Research.
H. Jackson, representing Wakool District Landowners' Executive (*Secretary*).

IRRIGATION RESEARCH EXTENSION COMMITTEE (MURRUMBIDGEE IRRIGATION AREAS).

C. G. Savage, Department of Agriculture, New South Wales (*Chairman*).
R. G. S. Kebby, Department of Agriculture, New South Wales.
B. O. French, Department of Agriculture, New South Wales.
H. Mallaby, Water Conservation and Irrigation Commission, New South Wales.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
E. R. Iredale, Rural Bank of New South Wales.
C. T. Lasscock, Rural Bank of New South Wales.
G. E. B. Good, Rural Bank of New South Wales.
E. S. West, B.Sc., M.S., Irrigation Research Station, Griffith.
R. R. Pennefather, B.Agr.Sc., Irrigation Research Station, Griffith.
D. V. Walters, M.Agr.Sc., Irrigation Research Station, Griffith.
V. C. Williams, M.I.A. Co-operatives Executive, Griffith.
O. J. Longhurst, M.I.A. Co-operatives Executive, Yenda.
W. Jacka, M.I.A. Co-operatives Executive, Leeton.
J. H. Carter, Rural Bank, New South Wales (*Secretary*).

TYNTYNDER INVESTIGATION COMMITTEE, SWAN HILL.

J. D. Wallis, State Rivers and Water Supply Commission, Victoria (*Chairman*).
J. A. Aird, B.Sc., B.Agr.Sc., State Rivers and Water Supply Commission, Victoria.
F. Rogerson, State Rivers and Water Supply Commission, Victoria.
A. V. Lyon, M.Agr.Sc., Commonwealth Irrigation Station, Merbein.
F. Penman, M.Sc., Department of Agriculture, Victoria.
E. Pearce, Swan Hill Advisory Board.
L. M. Barrett, Tyntynder Progress Association.

NYAH-WOORINEN INQUIRY COMMITTEE.

Hon. P. T. Byrnes, M.L.C. (*Chairman*).
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein.
J. A. Aird, B.Sc., B.Agr.Sc., State Rivers and Water Supply Commission, Victoria.
J. D. Wallis, State Rivers and Water Supply Commission, Victoria.
W. Bentley, State Rivers and Water Supply Commission, Victoria.
F. Penman, M.Sc., Department of Agriculture, Victoria.
F. M. Read, M.Agr.Sc., Department of Agriculture, Victoria.
D. D. Brown, Department of Agriculture, Victoria.
D. A. Cockcroft, Dried Fruits Board, Victoria.
A. McQueen, Department of Commerce.
A. S. P. Basey, Packers' Association.
A. Westcott, Woorinen Fruit Growers.
A. E. Jude, Woorinen Fruit Growers.
D. W. Cockcroft, Woorinen Fruit Growers.
H. Willoughby, Nyah Fruit Growers.
G. D. Willoughby, Nyah Fruit Growers.
R. Stevens, Nyah Fruit Growers.
L. M. Byrnes, Koraleigh Fruit Growers.
R. C. Polkinghorne (*Secretary*).

IRRIGATION ENGINEERING COMMITTEE.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, Merbein (*Chairman*).
J. A. Aird, B.Sc., B.Agr.Sc., State Rivers and Water Supply Commission, Victoria.
T. A. Lang, State Rivers and Water Supply Commission, Victoria.
F. H. Barrett, Water Conservation and Irrigation Commission, New South Wales.
F. B. Haigh, First Mildura Irrigation Trust.
J. G. Baldwin, B.Sc., B.Agr.Sc., Commonwealth Research Station, Merbein.
G. V. F. Clewett, B.E., Commonwealth Research Station, Merbein (*Secretary*).

COMMITTEE ON OENOLOGICAL RESEARCH.

Professor J. A. Prescott, D.Sc., representing the Council for Scientific and Industrial Research (*Chairman*).
C. Haselgrove, representing the Federal Viticultural Council.
Professor J. B. Cleland, M.D., Ch.M., representing the University of Adelaide.
L. N. Salter, representing the Australian Wine Board.

ADVISORY COMMITTEE ON FRUIT COOL STORAGE INVESTIGATIONS IN NEW SOUTH WALES.

C. G. Savage, Department of Agriculture, New South Wales (*Chairman*).
H. Broadfoot, Department of Agriculture, New South Wales.
Professor N. A. Burges, M.Sc., Ph.D., Department of Botany, University of Sydney.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R. (*Secretary*).

ADVISORY COMMITTEE ON FRUIT COOL STORAGE INVESTIGATIONS.

(*Established in connexion with the co-operative investigations of the Council and the Victorian Department of Agriculture on the cool storage of non-tropical fruits.*)

S. Fish, M.Agr.Sc., Department of Agriculture, Victoria.
F. M. Read, M.Agr.Sc., Department of Agriculture, Victoria.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.

COMMITTEE FOR CO-ORDINATION OF FRUIT AND VEGETABLE STORAGE RESEARCH.

W. M. Carne, Department of Commerce, Melbourne (*Chairman*).
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.
S. M. Sykes, B.Sc.Agr., Department of Agriculture, New South Wales.
F. M. Read, M.Agr.Sc., Department of Agriculture, Victoria.
A. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia.
T. D. Raphael, M.A., Dip.Hort. (Cambridge), Department of Agriculture, Tasmania.
S. A. Trout, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
T. C. Dunne, B.Sc. (Agric.) Ph.D., Department of Agriculture, Western Australia.
D. Martin, B.Sc., Division of Plant Industry, C.S.I.R.
R. B. Withers, M.Sc., Dip. Ed., Division of Food Preservation and Transport, C.S.I.R. (*Secretary*).

ADVISORY COMMITTEE ON ORIENTAL PEACH MOTH INVESTIGATIONS.

A. J. Nicholson, D.Sc., Division of Economic Entomology, C.S.I.R. (*Chairman*).
F. M. Read, M.Agr.Sc., Department of Agriculture, Victoria.
H. J. Williams, Leeton Co-op. Cannery Ltd., New South Wales.
G. A. H. Helson, M.Sc., Division of Economic Entomology, C.S.I.R.
S. Fish, M.Agr.Sc., Department of Agriculture, Victoria (*Secretary*).

JOINT BLOWFLY CONTROL COMMITTEE.

(Appointed as a means of co-ordinating the activities of the New South Wales Department of Agriculture, the Queensland Department of Agriculture and Stock, and of the Council for Scientific and Industrial Research.)

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R. (*Chairman*).
A. J. Nicholson, D.Sc., Division of Economic Entomology, C.S.I.R.
W. L. Hindmarsh, M.R.C.V.S., B.V.Sc., D.V.H., Glenfield Veterinary Research Station, New South Wales.
T. McCarthy, Department of Agriculture, New South Wales.
H. G. Belschner, D.V.Sc., Department of Agriculture, New South Wales.
F. H. S. Roberts, D.Sc., Department of Agriculture and Stock, Queensland.
D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R. (*Secretary*).

QUEENSLAND PRODUCERS' ANIMAL HEALTH COMMITTEE.

P. B. Newcomen, Queensland United Graziers' Association (*Chairman*).
N. Bourke, Queensland United Graziers' Association.
F. M. Bell, Queensland United Graziers' Association.
P. A. Brown, Queensland United Graziers' Association.
P. A. Elliot, Queensland United Graziers' Association.
G. A. Fairbairn, Queensland United Graziers' Association.
J. F. Meynink, Queensland United Graziers' Association.
R. C. Philp, Queensland United Graziers' Association.
J. L. Wilson, Queensland United Graziers' Association.
L. J. Landsberg, Queensland United Graziers' Association.
Professor D. H. K. Lee, M.Sc., M.B., B.S., D.T.M., University of Queensland.
J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Department of Agriculture and Stock, Queensland.
M. White, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
G. R. Moule, B.V.Sc., Department of Agriculture and Stock, Queensland.
L. F. Hitchcock, M.Sc., Division of Economic Entomology, C.S.I.R.
T. B. Paltridge, B.Sc., Division of Plant Industry, C.S.I.R.
A. R. Riddle, A.B., M.S., Division of Food Preservation and Transport, C.S.I.R.
C. H. Jamieson, Queensland Dairymen's State Council.
Miss H. F. Todd, C.S.I.R. (*Secretary*).

TECHNICAL COMMITTEE ON CATTLE TICK INVESTIGATIONS.

J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland (*Chairman*).
M. White, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
J. L. Wilson, Queensland United Graziers' Association.
A. W. Turner, O.B.E., D.Sc., D.V.Sc., Division of Animal Health and Production, C.S.I.R.
A. J. Nicholson, D.Sc., Division of Economic Entomology, C.S.I.R.
L. F. Hitchcock, M.Sc., Division of Economic Entomology, C.S.I.R.
F. H. S. Roberts, D.Sc., Department of Agriculture and Stock, Queensland.

TECHNICAL COMMITTEE ON BUFFALO FLY INVESTIGATIONS.

J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland (*Chairman*).
L. D. Carey, Department of Agriculture and Stock, Queensland.
A. J. Nicholson, D.Sc., Division of Economic Entomology, C.S.I.R.
K. R. Norris, M.Sc., Division of Economic Entomology, C.S.I.R.
A. W. Turner, O.B.E., D.Sc., D.V.Sc., Division of Animal Health and Production, C.S.I.R.

MINING ADVISORY COMMITTEE.

Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S., C.S.I.R. (*Chairman*).
H. Herman, D.Sc., M.M.E., B.C.E., Melbourne.
H. St. J. Somerset, Electrolytic Zinc Co. of Australasia Ltd., Melbourne.
W. E. Wainwright, A.S.A.S.M., Melbourne.
G. A. Cook, M.C., M.Sc., B.M.E. (*Secretary*).

Melbourne Sub-Committee.

H. Hey, Electrolytic Zinc Co. of A'sia Ltd., Melbourne (*Chairman*).
W. Baragwanath, Director, Geological Survey, Department of Mines, Victoria.
W. J. Rose, B.M.E., Commonwealth Tariff Board.
G. B. O'Malley, B.Met.E., Melbourne.
H. H. Dunkin, B.Met.E., School of Metallurgy, University of Melbourne.
R. B. Mills, B.Sc., Electrolytic Zinc Co. Ltd., Melbourne.
M. Mawby, Zinc Corp. Ltd., Melbourne.

Adelaide Sub-Committee.

L. Keith Ward, B.A., B.E., D.Sc., Adelaide (*Chairman*).
Professor Kerr Grant, M.Sc., Department of Physics, University of Adelaide.
S. B. Dickinson, M.Sc., Department of Mines, South Australia.
H. T. M. Angwin, C.M.G., B.E., F.S.A.S.M., Engineering and Water Supply Department, South Australia.
R. W. Parsons, Bonython Laboratory, South Australian School of Mines and Industries (*Secretary*).

Kalgoorlie Sub-Committee.

J. S. Foxall, B.E., Department of Mines, Western Australia.
R. A. Hobson, B.Sc., School of Mines, Kalgoorlie, Western Australia.
F. G. Brinsden, Australasian Institute of Mining and Metallurgy, Western Australia.
J. R. Hylton, Great Boulder Pty. Gold Mines Ltd., Fimiston, Western Australia.

CORROSION ADVISORY COMMITTEE.

I. W. Wark, Ph.D., D.Sc., Division of Industrial Chemistry, C.S.I.R.
C. M. Longfield, State Electricity Commission, Victoria.
R. J. Bennie, Metropolitan Gas Company, Melbourne.
C. G. H. McDonald, Department of Railways, Victoria.
C. J. Griffiths, Postmaster-General's Department, Melbourne.
S. S. Robertson, Melbourne and Metropolitan Tramways Board.
L. Lewis, B.Met.E., Division of Industrial Chemistry, C.S.I.R. (*Secretary*).

AVIATION RADIO RESEARCH COMMITTEE.

E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R. (*Chairman*).
R. M. Badenach, Department of Civil Aviation.
C. S. Wiggins, Department of Civil Aviation.
Wing-Commander J. W. Reddrop, Director of Telecommunications and Radar, Department of Air, Melbourne.
S. H. Witt, Postmaster-General's Department.
M. H. Meyers, Qantas Empire Airways Ltd.
O. L. Wirsu, B.Sc., B.E., Australian National Airways Pty. Ltd.
J. H. Gerrand, Australian National Airlines Commission.
Captain A. C. Lovell, Australian Air Pilots' Association.
F. G. Nicholls, M.Sc., C.S.I.R. (*Secretary*).

AERONAUTICAL RESEARCH CONSULTATIVE COMMITTEE.

Professor A. V. Stephens, M.A., Sydney (*Chairman*).
Professor T. M. Cherry, B.A., Ph.D., Melbourne.
W. A. S. Butement, O.B.E., Long-range Weapons Organization.
Air Vice-Marshall E. C. Wackett, O.B.E., R.A.A.F.
M. B. Woodfull, Division of Aircraft Production, Munitions Department.
E. G. Bowen, O.B.E, M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.
L. P. Coombes, D.F.C., B.Sc. (Eng.), Division of Aeronautics, C.S.I.R.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.
G. B. Gresford, B.Sc., C.S.I.R. (*Secretary*).

METEOROLOGICAL RESEARCH CONSULTATIVE COMMITTEE.

R. v. d. R. Woolley, M.A., M.Sc., Ph.D., Mt. Stromlo Observatory (*Chairman*).
Professor Sir John Madsen, B.E., D.Sc., University of Sydney.
F. Loewe, Ph.D., University of Melbourne.
E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.
C. H. B. Priestley, M.A., C.S.I.R.
G. B. Gresford, B.Sc., C.S.I.R. (*Secretary*).

ATOMIC ENERGY RESEARCH ADVISORY COMMITTEE.

F. W. G. White, M.Sc., Ph.D., C.S.I.R. (*Chairman*).
Major-General L. E. Beavis, C.B.E., D.S.O., Department of Defence.
A. P. Rowe, C.B.E., Department of Defence.
S. B. Dickinson, M.Sc., Department of Mines, South Australia.
Professor L. H. Martin, Ph.D., University of Melbourne.
H. G. Raggatt, D.Sc., Department of Supply and Shipping.
G. H. Briggs, D.Sc., Ph.D., C.S.I.R.
I. W. Wark, D.Sc., Ph.D., C.S.I.R.
G. B. Gresford, B.Sc., C.S.I.R. (*Secretary*).

TRACER ELEMENT RESEARCH COMMITTEE.

C. E. Eddy, D.Sc., Department of Health.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.
F. G. Nicholls, M.Sc., C.S.I.R. (*Secretary*).

COAL DUST RESEARCH ADVISORY COMMITTEE.

Professor F. A. Eastaugh, A.R.S.M., F.R.I.C., Sydney (*Chairman*).
G. C. Smith, M.B., B.S., Department of Health, New South Wales.
H. M. Whaite, Department of Health, New South Wales.
C. D. Durham, Department of Mines, New South Wales.
J. C. Webb, Education Department, New South Wales.
A. T. R. Emery, Australian Coal and Shale Employees' Federation, New South Wales.
J. Sneddon, Australian Coal and Shale Employees' Federation, New South Wales.
F. M. Jefferson, Australasian Institute of Mining and Metallurgy.
G. M. Hindmarsh, New South Wales.
S. McKensey, New South Wales.
C. O. Newey, New South Wales.
H. L. Pearce, New South Wales.
O. G. Vickery, New South Wales.
L. F. D. Cane, New South Wales.
G. B. Gresford, B.Sc., C.S.I.R. (*Secretary*).

Printed and Published for the GOVERNMENT of the COMMONWEALTH OF AUSTRALIA by
L. F. JOHNSTON, Commonwealth Government Printer, Canberra.