physics in the CSIRO

(otherwise, the Commonwealth Scientific and Industrial Research Organization of Australia)

By Yardley Beers

"THE CSIRO? I know of them. They do a lot of radio astronomy", said the custom's agent who examined my baggage. "The CSIRO? They certainly have shown that research pays, especially in the way in which they have reduced the rabbit pest", said a retired business man. "Yes, we all know about the CSIRO. Wonderful work they have done", said the owner of a sheep ranch. Remarks similar to these soon assured me that the Australian people nearly were as familiar with the initials "CSIRO", as with the words "kangaroo" and "tennis" and that they had been convinced of the value of basic research.

The institution denoted by these initials, the Commonwealth Scientific and Industrial Research Organization, was established in 1949 by an act of the Australian Parliament for carrying out research in connection with industry, training of research workers, testing of scientific apparatus, and the collection and dissemination of information relating to scientific matters. It is the successor to two previous organizations, the Institute of Science and Industry and the Council for Scientific and Industrial Research, which had existed during the previous three decades. Now it maintains laboratory buildings in all of the principal cities, has a professional and technical staff of about 1400 people and operates on an annual budget of about $12.5 million dollars, about three-quarters of which is obtained from governmental sources and the remainder from industry. These statistics are particularly impressive when it is realized that Australia has a population of only about nine million, and at the same time it supports other agencies, working in fields outside the scope of the CSIRO. The CSIRO does not do research in atomic energy and classified defense work. Most nuclear research is supported by the Atomic Energy Commission. Although the larger part of the effort of the CSIRO is devoted to industrial research, this is almost entirely confined to broad general problems rather than to petty gadgeteering and trouble shooting. The Organization is best known to the general public for its work on reducing the rabbit pest by the artificial induction of myxomatosis and for its work on the nutrition of sheep and the conversion of the Ninety Mile Desert into a productive area.

However, the objectives of the CSIRO could not be fulfilled without an extensive program in basic physics, and several of its units are largely concerned with such a program. These consist of the three divisions comprising the National Standards Laboratory and the Division of Radiophysics in Sydney, the Division of Tribophysics and the Section of Chemical Physics of the Division of Industrial Chemistry in Melbourne. Furthermore, physicists contribute valuable service in many other units such as the Division of Plant Industry, the Division of Forest Products, the Division of Meteorological Physics, and the Division of Building Research.

The National Standards Laboratory came into existence almost instantaneously as a consequence of the demands of industry during World War II for the standardization of its measurements, although some plans for its establishment had been made previously. The organization of a full-fledged laboratory of this type without the advantage of experienced personnel presented some serious problems, but the Laboratory had the initial advantage of starting out with completely new equipment. It has a staff of about one hundred and it is housed along with the Division of Radiophysics in a modern building located on the grounds of the University of Sydney, and considerable mutual benefit is obtained through informal collaboration with the University. While much of the time of the laboratory must be employed on calibration services, there is in progress a large program of basic and applied research.

ADMINISTRATIVELY, the National Standards Laboratory consists of three Divisions: Metrology, Physics, and Electrotechnology. The Division of Metrology (the name is derived from the Greek word "metron" and is not to be confused with "meteorology") has the responsibility of maintaining the standards employed in mechanics: not only of mass, length, and time but also of such derived quantities as density and pressure. The

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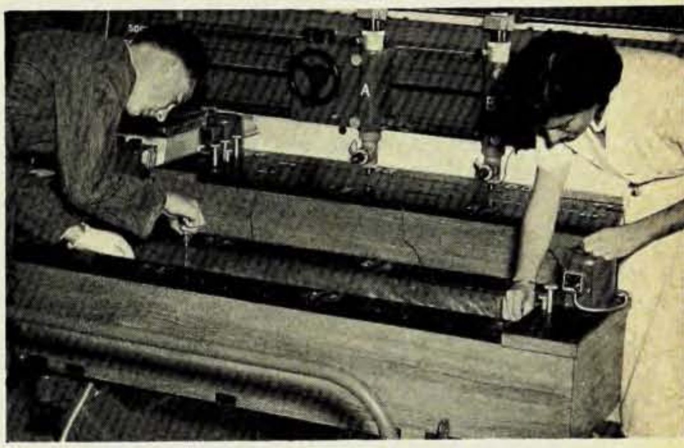
CSIRO National Standards Laboratory, Sydney. The Division of Radiophysics is housed behind the Standards Laboratory.

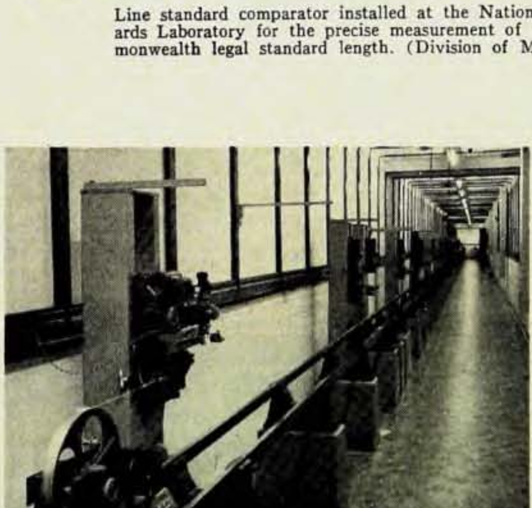
chief of the Division, N. A. Esserman, is a member of the International Committee on Weights and Measures. The Section of Length Measurement, headed by M. J. Puttock, possesses facilities for comparing line standards, surveyors' tapes, and end standards with accuracies of one or two parts per million. In the measurement of short lengths and in other activities such as the accurate measurement of angles, the Section employs numerous interferometric techniques. The Section also has comprehensive facilities for checking all types of gauges, screws, and measuring instruments, and for checking the alignment of machine tools, rolling mills, and similar installations.

The Section of Mass Measurement not only maintains the Standards of mass but also provides calibration facilities for volumetric glassware, density, and pressure. In spite of its name it also calibrates stopwatches and chronometers, does some testing of aerial cameras, and carries out studies on abrasives and lapping of surfaces. The head of the Section, G. A. Bell, has recently developed a method for the differential measurement of changes of density which has proved to be of great importance to the Division of Tribophysics in the study of dislocations in metals. Another current development is a new standard barometer in which the technique for measuring small changes in electrical capacitance devised by the Division of Electrotechnology (and as described below) is used for determining the position of the top of a mercury column.

The Section of Interferometry, headed by C. F. Bruce, is carrying out basic investigations in this field. One of its principal concerns at this moment is the study of single isotope atomic line sources of light. A recent investigation by Thornton [1] has shown that proton tracks in stripped nuclear emulsions can be detected by microinterferometric methods. The Section of Electronics, led by H. A. Ross, has built devices for the automatic control of temperature and pressure and also has developed apparatus for measuring periodic errors in machines. The Applied Mechanics Section, of which C. A. Gladman is the leader, is the largest section in the Division. It maintains standards of force and hard-



Line standard comparator installed at the National Standards Laboratory for the precise measurement of the Commonwealth legal standard length. (Division of Metrology)



50-meter geodetic base installed in Metrology Division of National Standards Laboratory for calibration of surveying tapes to an accuracy of 2 parts in 10^6.

[1] B. S. Thornton, Aust. J. Physics 7, 652 (1954)

ness. It devotes much of its time to development of techniques for the analysis of engineering designs, to the study of vibration and isolation measurement, the machining of materials, and problems of production engineering.

THE Division of Electrotechnology is responsible for maintenance of the standards of electrical measurement and, in conjunction with the Commonwealth Observatory, of the standards for the measurement of frequency. The head of the Division is F. J. Lehany. One of the most important research projects within the Division results from the proof of a new theorem in electrostatics by which it has been shown that the direct capacitance between two alternate pairs of cylinders whose configuration has a plane of symmetry is $(\ln 2)/(4\pi^2)$ electrostatic units per cm of length.[2] On the basis of this theorem new standard three-terminal capacitors have been constructed. The present work is an attempt to redetermine the ohm in terms of such a capacitance and of the accepted value of the velocity of light.

Unfortunately it is impractical to build such a device with a direct capacitance of greater than about one micromicrofarad while a much larger capacitance is required for the determination of the ohm. Therefore two intermediate steps are required. In the first, the three-terminal standard capacitor is used to calibrate a conventional two-terminal capacitor having approximately an equal capacitance. Then the latter is compared to the much larger two-terminal capacitance which is used in the determination of the ohm. These comparisons are effected by the use of bridge circuits at 1000 cps employing toroidal transformers to supply the ratio arms. These transformers have been developed in the laboratory and have a turns ratio known to one part in a hundred million. With such bridges a capacitance change of a millionth of a micromicrofarad can be detected.

The present model of the three-terminal capacitor employs guard rings to correct for end effects. However, in the final model the correction will be made by changing the length. The change in length will be measured by an interferometer which will be incorporated in the design. It is hoped that a capacitance standard having an accuracy of one part in ten million and a determination of the ohm with an accuracy of one part in a million can be obtained. These techniques for measuring small capacitances have been applied to a number of instruments such as the barometer which has been mentioned in connection with the work of the Division of Metrology.

A large program under the direction of R. J. Meakins is concerned with the investigation of the relationship between the structure and dielectric properties of electrical materials. At the present stage the work involves the preparation of pure chemical compounds and the measurement of their loss factor and dispersion at frequencies between 10^{-4} and 3.5×10^{10} cps. Most of the work has been carried out with organic compounds, but more recently a program on the behavior of alkali halides containing traces of divalent impurities has been commenced. In addition, D. W. Posener is engaged in the microwave spectroscopy of gases and has available equipment employing stabilized oscillators and oversize Stark-modulated waveguide absorption cells. He has been able to obtain a high degree of resolution of the hyperfine splitting of D_2O and HDO lines. There is also a program under the leadership of D. G. Lampard for studying the effect of noise in nonlinear networks. The Division is further engaged in the development of various types of instrumentation which include devices for measuring magnetic fields, the temperature and salinity of sea water, and some auxiliary equipment for the Shoran radio navigational aid.

THE Division of Physics, under its chief, G. H. Briggs, is responsible for maintaining standards of heat, light, and viscosity. The Heat Section, headed by A. F. A. Harper, in addition to its standards work, performs research in low-temperature physics. The facilities include a Collins helium liquifier and a mass spectrograph leak detector, both constructed within the laboratory. Studies of the imperfections of metals and alloys are made by determining the electrical and thermal conductivities and the specific heats as a function of temperature.[3] The experimental work is under the direction

[2] A. M. Thompson and D. G. Lampard, Nature **177**, 888 (1956)

[3] P. G. Klemens, *Encyclopedia of Physics* (Springer, Berlin, 1956) Vol. 14, p. 198

J. W. Smyth operates Collins-type helium liquifier built by Division of Physics. Because of shortage of dollars, Australian physicists frequently must build apparatus which their American colleagues usually buy. The Division has also built a mass spectrograph leak detector.

of W. R. G. Kemp, and the theoretical interpretation is due to P. G. Klemens. Another project in this Section is the development of a hygrometer [4] operating on a novel principle and having a high sensitivity and high speed of response. This employs the change in surface electrical conductivity of ionic crystals due to the layer of absorbed water vapor in equilibrium with the atmossphere whose humidity is to be determined when the crystal is maintained at some standard temperature. Alternatively, the equilibrium temperature may be measured when a feedback network connected to the heating element controls the generation of heat to maintain the conductivity at some preassigned value. Associated with this work there is also a program for studying the vapor pressure of the water adsorbed on such crystals as a function of temperature.

One of the programs in the Light Section is a project on contrast transfer functions directed by W. H. Steel. This technique, which is employed in a number of laboratories, utilizes a modification of information theory for the study of the resolving power of optical instruments. The present project is concerned with a new technique for producing object patterns having known sinusoidal contrast variations with variable degrees of coherence.[5] In another project, R. G. Giovanelli is doing theoretical work on radiative transfer phenomena: that is, the passage of radiation through absorbing and scattering media.[6] The theory is general and it may be applied to such diverse media as stellar atmospheres on one hand and paints and pigments on the other. In addition there is a program, both experimental and theoretical, in solar physics. Theoretical methods have been developed for predicting the strengths of spectral lines emitted and absorbed by hot atmospheres in the absence of thermodynamic equilibrium, and this is being applied to the interpretation of solar flares and prominences.[7] Since the beginning of 1956 a spectroheliograph operating on the roof of the Laboratory in Sydney has been obtaining H_α filterograms at half-minute intervals on a routine basis for studies of chromospheric flares and associated phenomena. Under construction thirty miles west of Sydney, adjacent to the Fleurs Radio Astronomy Field Station, is a new spectroheliograph which will ultimately include a new filter intended primarily for studying chromospheric granulation. This filter, to be composed of 56 optical elements, is to have a line width of one-eighth of an Angstrom unit. The center frequency is to be swept over the H_α line for the observation of temperature variations and Doppler shifts by rotating some of the optical components.

[4] R. G. Wylie, Nature, **175**, 118 (1955)
[5] W. H. Steel, Revue d'Optique **32**, 4, 143 and 269 (1953)
[6] R. G. Giovanelli and J. T. Jefferies, Proc. Phys. Soc. (to be published)
[7] J. T. Jeffries and R. G. Giovanelli, Aust. J. Phys. **7**, 574 (1954); J. T. Jefferies, Monthly Notices, R. A. S. (to be published)

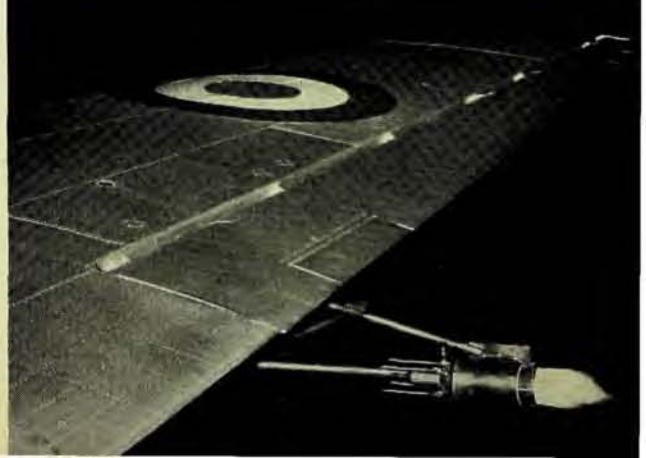
THE Division of Radiophysics, whose headquarters is housed in the same building in Sydney as the National Standards Laboratory, is engaged in the following fields of research: radio astronomy, radio propagation, cloud physics, and transistors. As a successor to the war-time Radiophysics Laboratory, which was concerned with the development of radar and radio navigational devices, it entered into these programs as the result of natural evolution.

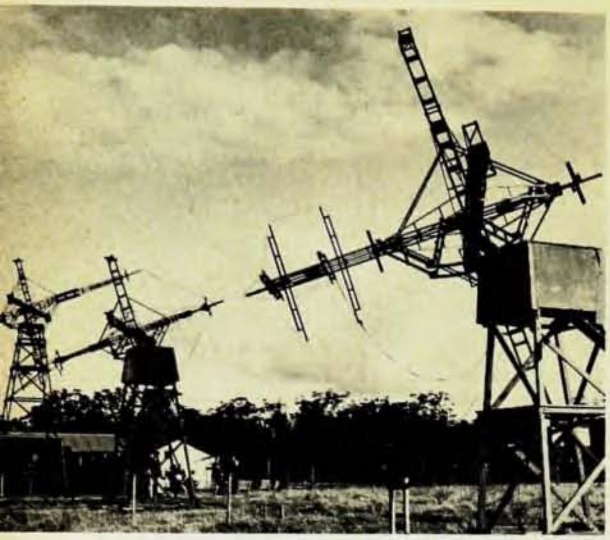
The radio astronomy program, under the direction of the assistant chief of the Division, J. L. Pawsey, has several projects. One of these is a survey of the sky with radiation from the continuous spectrum with two Mills cross type systems located at the Fleurs Field Station. The original Mills cross [8] employs two arrays of dipoles 1500 feet long and operates at 85 Mc/sec. These arrays intersect at right angles at their centers and feed separate frequency converters which have a common local oscillator. The outputs are combined in a common IF amplifier. The phase of one of the local oscillator signals is reversed at a periodic rate, and thus the IF signal is amplitude modulated at the switching frequency. This signal feeds a phase detector which derives its reference voltage from the source of switching voltage. By this technique, the effective spatial response is the product of the patterns of the two arrays, and thus a narrow pencil beam having a width of 50 minutes is produced. To obtain such a narrow beam without electronic mixing but by a configuration of dipoles having a single feed and thus forming a single antenna, it would be necessary to have one approximately occupying an entire square 1500 feet on a side rather than two straight-line arrays 1500 feet long. For

[8] B. Mills, Aust. J. Phys. **6**, 272 (1953)

D. W. Posener operating microwave spectrometer. (Division of Electrotechnology)

Aircraft equipped with generator for seeding clouds with silver iodide smoke. (Division of Radiophysics)

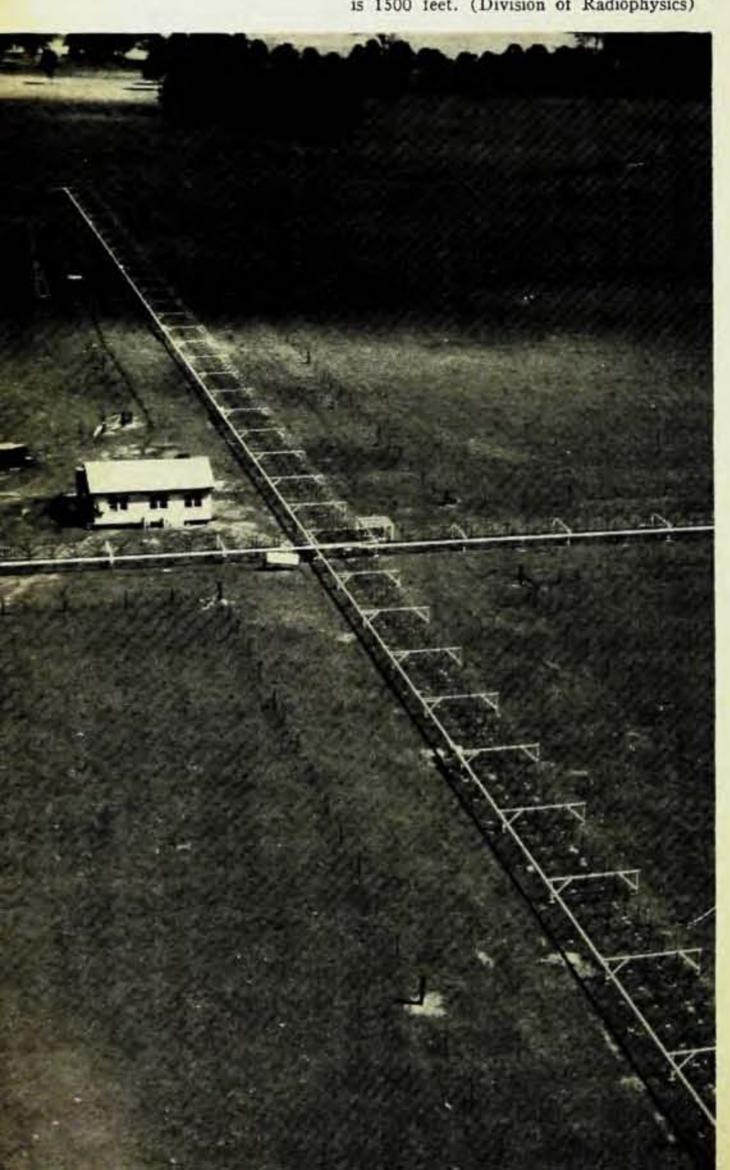




Rhombic antennas for observation of the sun at the Dapto Field Station near Wollongong. (Division of Radiophysics)

J. W. Telford operates vertical wind tunnel used for investigating coalescence between droplets in a cloud. (Division of Radiophysics)

85 Mc Mills Cross Antenna, Fleurs Field Station. Total length of each line of dipoles is 1500 feet. (Division of Radiophysics)



the location of discrete sources this antenna system and another several kilometers away are connected by a radio link to form an interferometer. The center of our own galaxy has been investigated and brightness contours plotted. In addition, a number of discrete extragalactic sources have been observed, and many of the nearer external galaxies have been identified. From these data it has been possible to make some statistical conclusions concerning emission characteristics. Recently a second apparatus with a Mills cross antenna having 3500 foot arrays at 19.7 Mc/sec with a beam width of 1.5 degrees has been put into operation.

1420 Mc/sec hydrogen line studies are made at the Potts Hill and Murray Bank Field Stations on the outskirts of Sydney. The former, under the direction of F. J. Kerr, uses a 32-foot parabolic antenna and a five channel receiver and has been making observations of the Southern Milky Way. The latter is the site of the development of a new receiver having about 40 IF channels, each 40 kc/sec wide, which will permit recording the entire line profile at one time. This station employs an 18-foot antenna and will be used for general survey work.

Solar investigations directed by J. P. Wild are carried out at the Dapto Field station, about fifty miles south of Sydney. This station employs wide-band rhombic antennas of comparatively low gain for the rapid observation of the spectrum between 40 and 240 Mc/sec in connection with the study of flares. In addition, at Fleurs there is under construction under the direction of W. N. Christiansen a new instrument of high resolution for observing the detailed brightness of the sun. This will employ two 1240-foot arrays of thirty-two 19-foot diameter parabaloids arranged in a "cross". Each parabaloid will be mounted in such a way as to track the sun.

The recent gifts of $250 000 each from the Carnegie Corporation and from the Rockefeller Foundation as well as other gifts from Australian donors has led to design studies of a giant radio telescope. The present conception is a 300-foot parabolic antenna suitable for use at a wide range of frequencies.

The work on Cloud and Rain Physics is under the direction of the chief of the Division, E. G. Bowen, and had its origin in the former work of the Radiophysics Laboratory in using radar to track clouds. One phase of this work is the study of the fundamental processes which cause precipitation. Observations are being made on the size spectrum of the droplets in clouds. Also it is found that droplets are electrically charged, and the rate of coalescence can be effected by applying electric fields. The concentration of freezing nuclei, is observed by passing a sample of air into a "cold box" carried in an airplane and letting the crystals fall into a liquid solution at the bottom of the chamber, where they grow in size and can be counted by eye. Statistical studies of rainfall and meteor showers indicate a strong correlation between them. This appears to be due to the action of meteoric dust particles as condensing nuclei. Further evidence for this hypothesis is being sought by the studies of dust by the scattering of sunlight. Correlation with the radar studies of meteor tracks by L. G. H. Huxley at the University of Adelaide also is being sought.

The properties of silver iodide for seeding of clouds have been investigated. Recently it has been found that the effectiveness of silver iodide decreases rapidly after its release during daytime but not at night, probably because of photodisintegration, and therefore daylight seeding can be effective only when the silver iodide is released directly into the cloud. Long-range seeding experiments are being carried out over two large hydroelectric projects in Southeastern Australia, but no definite results are available as yet.

A small group of scientists is working under the direction of L. W. Davies on transistors and transistor circuits. First there are experiments upon the growth of single crystals of silicon and germanium. Secondly, the group is developing some high powered alloyed-junction transistors. Thirdly, an experimental model of a nearly transistorized version of the DME (Distance Measuring Equipment) is under construction. The DME is a 200 Mc/sec airborne radio navigational device.

The Division of Radiophysics carries out some work on the propagation of radio signals. Natural noise levels are being measured throughout Australia. Also certain propagation anomalies are being investigated.

Other work on propagation is carried out by the Radio Research Board, which is administered by the CSIRO and which is headed by D. F. Martyn. This has its headquarters on the grounds of the University of Sydney and field stations at Camden about fifty miles southwest of Sydney and at Mt. Stromlo, near Canberra. Its work concerns ionospheric studies, and also it makes ionospheric predictions.

ONE of the largest Divisions of the CSIRO is the one of Industrial Chemistry, located at Fisherman's Bend, Melbourne, and headed by I. W. Wark, a physical chemist. Its Section of Chemical Physics, however, is devoted to work in physics almost entirely, and the size of this Section is comparable to that of many other Divisions. The leader of the Section is A. L. G. Rees.

The multiple-pass principle which has been incorporated in Perkin-Elmer infrared spectrometers was invented by A. Walsh working in this Section.[9] At present this principle is being applied to other instruments including a Raman spectrometer. Recently Walsh has devised a scheme for observing atomic absorption spectra of metallic vapors. This is to form the basis of commercial instruments for chemical analysis. High sensitivity is achieved by chopping the light from a resonance source which passes through a flame containing the sample being analyzed. The transmitted light gives rise to an ac signal in the output of a photomultiplier located at the exit slit of a monochrometer while the light emitted by the flame gives rise to a dc signal which can be easily eliminated.

High-resolution electron diffraction studies with small crystals [10] and with very oblique incidence on uniform surfaces yield patterns which can be analyzed by Fourier methods. These are useful not only in determining general structure but particularly for measuring the range of order in partially ordered structures. Also these techniques are useful for locating hydrogen bonds. In parallel with this work is that on single-crystal x-ray diffraction [11] which has made possible the structural determination of moderately complex molecules without any initial information other than the empirical formula. Structures of molecules with as many as about 30 atoms have been determined.

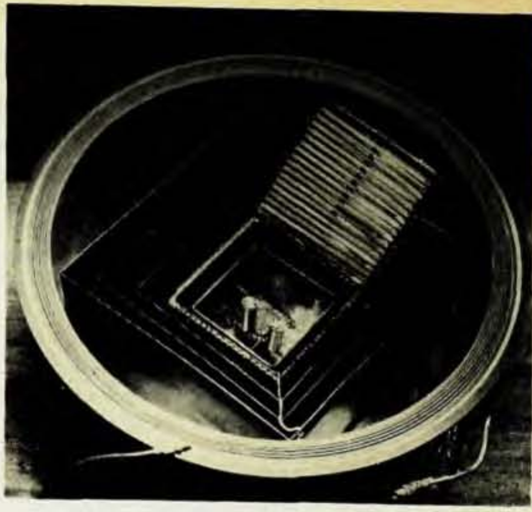
Associated with these investigations is the construction of a special image-seeking computer for determining directly the structures from Patterson diagrams obtained by electron diffraction and x-ray diffraction.

High-resolution electron impact spectra are obtained by applying ac modulation to the electron gun of a mass spectrometer and by connecting a phase sensitive detector to the collector.[12] In this way changes in slope of the current vs. electron energy curve may be located very precisely, and it is possible even to determine excitation potentials corresponding to vibrational excitation.

THE Division of Tribophysics is located in a modern building on the grounds of the University of Melbourne. It was first created during the war for the purpose of the study of friction in bearings and the effect of lubricants, as its name suggests. Now it is almost entirely devoted to fundamental investigations of imperfections in metals [13] and of the chemistry of surfaces. The chief of the Division, W. Boas, recently has been visiting Gordon McKay Lecturer on Metallurgy at Harvard University.

The most important technique devised here is a calorimeter [14] for measuring the energy released when strained metals are annealed. In this the strained sample and an annealed sample, otherwise as nearly identical

[9] A. Walsh, J. Opt. Soc. Am. **42**, 94, 96 and 496 (1952)
[10] J. M. Cowley, Acta. Cryst. **6**, 516, 522 and 846 (1953); A. L. G. Rees, Proc. Roy. Soc. (N. S. W.) **86**, 38 (1952).
[11] A. McL. Mathieson, Revs. Pure Appl. Chem. **5**, 113 (1955)
[12] J. D. Morrison, Revs. Pure Appl. Chem. **5**, 22 (1955)
[13] W. Boas, Aust. J. Sci. **16**, 122 (1954)
[14] Clarebrough, Hargreaves, and West, Proc. Roy. Soc. **A232**, 252 (1955)



Division of Tribophysics apparatus includes special vacuum calorimeter (above) in which deformed and annealed specimens of metal are heated together. Energy stored during deformation is released as specimen is heated to its annealing temperature, and measurement of the released energy as a function of temperature yields information on the roles of lattice defects, dislocations, vacancies, etc., in the deformation and annealing processes.

Below: Frictional force between hemispherical slider and flat plate is measured with Bowden-Leben apparatus to show variations in load, sliding speed, temperature of surfaces, etc.

as possible, are heated and maintained at equal temperatures, and the difference in energy is recorded by a special differential wattmeter. The amount of energy released per unit work of deformation of copper is found to be independent of the impurity concentration for small amounts but the rate of the release of energy as function of temperature is very dependent upon the impurity concentration. From the study of the rate of release of energy deductions may be made concerning the nature of the imperfections. These data are also correlated with observations upon electrical conductivity, hardness, macroscopic density, and the distribution of intensity in x-ray diffraction patterns.

In the field of chemistry of surfaces, the principal line of investigation which is being followed is the study of catalytic action of single crystalline surfaces. The activation energy for the decomposition of formic acid on silver has been found to depend upon the crystal orientation.[15] As an adjunct to this investigation, studies are being made on the preparation of surfaces. Particular attention has been given to the thermal etching of silver. Also work is being done on the formation of thin films and adsorption on solid surfaces.

RESEARCH in physics is aided by various mathematical groups. The Division of Mathematical Statistics, with headquarters at the University of Adelaide, assists many of the other Divisions. An electronic computer originally built by the Division of Radiophysics is now operated by the Physics and Mathematics Departments of the University of Melbourne. A differential analyzer is operated by the Mathematical Instruments Section of the CSIRO at the University of Sydney.

In addition to its own participation in research, the CSIRO sponsors research in the universities, either by itself or in collaboration with such agencies as the Electrical Research Board and the Radio Research Board. Notable among the sponsored projects are the cosmic-ray and biophysics projects at the University of Tasmania and a project on the loss electrode material in electric arcs at the University of New England, Armidale, N. S. W.

However, the Organization's prerogative to sponsor research is not viewed as an unmitigated blessing by all university people. D. M. Myers [16] has pointed out that whereas the value of the CSIRO to the universities and to industry has been tremendous and that, whereas any worth-while research project at a university has reasonable hope of receiving support from the CSIRO, the virtual monopoly of the Organization of the resources for research in natural sciences is potentially dangerous, and he recommends the establishment of an independent governmental body for sponsoring university research.

The Organization supports the overseas studies of about twenty-five graduate students through its studentships. In addition about one in about each twenty-five regular members of the staff make trips to Europe or the United States, or usually both, each year either on CSIRO sponsorship or on invitation of institutions abroad.

It also maintains library facilities at all its centers, and these contain excellent collections not only of the published literature but also of unpublished reports and reproductions of PhD theses from abroad. Translators are available at some of the larger centers. The Organization also publishes and edits eight of the principal Australian scientific journals, including the *Australian Journal of Physics*.

Because of its high standards and its wide range of activities the CSIRO is taking a place amongst the world's leading research organizations. Americans should have occasion to hear even more of it in the future.

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[15] H. M. C. Sosnowsky, J. Chem. Phys. **23**, 1486 (1955)

[16] Speaking at a symposium on The Place of the Australian University in the Community and Postgraduate Studies in the Australian Universities, August 11 and 12, 1955. Copies of papers available from the Secretary, Australian Vice Chancellors' Committee, c/o Australian National University, G. P. O., Box 4, Canberra, A. C. T.