2.1.8.3

13/1965

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF PHYSICAL SCIENCES

DEPARTMENT OF PARTICLE PHYSICS

Annual Report to Council for 1964

Staff

Professor and Head of Department:	Sir Mark Oliphant, K.B.E., F.R.S. (Resigned June, 1964)
Senior Research Engineer (Senior Fellow) and Acting Head:	J.W. Blamey, M.Sc.
Senior Research Engineer (Senior Fellow):	E.K. Inall, B.E., Ph.D.
Senior Fellow:	D.S. Robertson, B.Sc., Ph.D. (Left October, 1964)
Senior Research Fellow:	B.S. Liley, M.Sc., Ph.D.
Fellow:	R.A. Marshall, B.Sc., B.E., S.M. (On study leave from May, 1964)
Research Engineers (Fellows):	P.O. Carden, B.E. C.F. Vance, M.Sc. T.W. Brady, B.Sc., A.M.I.E.E. (Arrived April, 1964)
Research Fellow:	A.H. Morton, D.F.C., M.Sc., Ph.D. (Returned October, 1964)
Research Student:	E.L. Bydder, M.Sc.
Exchange Visitor:	A.N. Lebedev, Candidate in Physics and Mathematics. (Arrived March, left December, 1964).

Departmental Organization

In June, 1964 Professor Sir Mark Oliphant relinquished his position as Head of the Department. During an interim period with Professor J.C. Jaeger as Acting Head, the structure of the Department was re-organized.

A "Physics of Ionized Gases" Unit was established with Professor Oliphant as head and the physical chemistry group was also

detached as a "Diffusion Unit" with Dr. R. Mills as head. These units are financed for the present triennium from the Departmental budget and quota. The work of these units is reported elsewhere.

In July, 1964, Mr. J.W. Blamey was appointed Acting Head of the Department which retained responsibility for the development and application of the homopolar generator and plasma physics. Pending a review of the work of the Department, the filling of staff vacancies was suspended and commitments restricted to a minimum.

Staff Movements

Prior to his resignation, Professor Oliphant visited overseas establishments in January and February.

Mr. T.W. Brady was appointed in April as an engineer to be associated with the homopolar generator and its operational maintenance and control.

Dr. D.S. Robertson left in October on leave without pay to work at B.N.L.

Dr. A.H. Morton returned in October from A.E.R.E., Culham after 2½ years leave, to work in Plasma Physics.

Mr. R.A. Marshall departed for one years study leave in June, returning for six weeks in September during testing of the homopolar generator.

Mr. A.N. Lebedev worked in the Department on Plasma Physics under the Exchange Visitors Scheme with the University of Moscow from March to December.

General

The work of the Department is centred around the homopolar generator and to a limited degree its applications. The unique and outstanding characteristics that justified its development are mainly its high energy storage, its ability to provide large currents at large powers (potentially 500 to 1,000 megawatts) and its low internal impedance, all for relatively low capital cost.

The initial aim of the Department was research in high energy particle physics, the entry into which was to be achieved by the construction of an accelerator. In 1953 the Department embarked upon the development of a 10 GeV ironless synchrotron with a homopolar generator as the power supply for its magnetic field. No insuperable technical obstacles were encountered, but for cogent reasons - mainly the very costly and potentially better developments abroad, and too limited man power here - completion of the synchrotron was virtually suspended in 1957. The development of the generator was continued, both for its own sake, and for its potential in promoting advancement in several fields of physics. The best applications would however require serious parallel development in appropriate research fields. For several obvious, if not generally accepted reasons, little was done about this, apart from establishing some research in plasma physics in a preparatory though minor fashion and at a lower level than intended.

It is hoped that, in spite of its many omissions, the preceding paragraph, together with recognition of the chronic limitations in man power explain why applications have been considered to a limited degree only. The Department is currently undertaking some experimental and theoretical work in plasma physics and is also making preparation for the operation of high field magnets powered by the homopolar generator.

Homopolar Generator

The Department has continued with the development of the generator and has achieved success in its program of converting it to operation with solid brushes and modified oil and gas bearings. The solid brush system was tested on one rotor in September, October and December, at up to 800,000 amperes (half full current) and up to $\frac{2}{3}$ full speed in about 400 pulses. The behaviour was satisfactory and in accordance with the indications from model tests and analysis in 1963.

Whilst solid brushes had been used successfully for several years (before the liquid metal tests) in accelerating the rotors to full speed, only liquid metal had been deemed capable of operating at both full speed and full pulse current with reasonable efficiency. The significance of the 1964 brush tests is that usefully large and possibly full power can be taken from the generator with solid brushes, thus avoiding the hazards and great inconvenience of the NaK and other liquid metal systems.

The value of the homopolar generator as a sound and useful project has been under review and during the year a number of consultants were engaged to assist the University in arriving at an accurate and objective assessment.

The uniqueness and value of the homopolar generator as a pulse power supply was recognized as was also the difficulty of taking full advantage of its capabilities within the A.N.U. at the present time, or in the very near future. The line of development followed and the modifications of the last few years were confirmed as probably the best. However, it was also advised and at present accepted, that more emphasis should be placed on short term objectives and immediate applications rather than to demonstrate its full power in a field of research possibly foreign to University policy or too demanding in resources.

To this end, the generator is being completed to an intermediate output stage, with its application confined to the operation of ultra-high field magnets. The earlier proposal to apply it to the production of large magnetic fields and high temperatures for research in plasma physics has been suspended at least until this is more clearly justified as within the aims and resources of the A.N.U., and/or by progress abroad.

Intensive effort has gone into the modification of the homopolar generator for use with solid brushes and in preparation for the tests towards the end of the year. A full set of brushes for the lower disc of

the lower rotor were made in the laboratory. 864 outer brushes are mounted in 72 blocks of 12 and the inner brushes in 36 blocks of 16. Half of these were installed for the tests which were at half full current, so that individual brushes were operated at full current density. A comprehensive array of instruments for observation of temperature, voltage drops currents and general brush behaviour,were fitted and wired to recording devices in the control room.

Pneumatic brush actuators and their high pressure air supply, pipe lines, valves and controls were installed using existing equipment such as the NaK high pressure storage tanks.

The NaK circulating system has been dismantled, cleaned and stored, and the NaK itself transferred from the generator and shipping drums into special sealed storage drums using nitrogen as cover gas.

The upper rotor bearing system was completed and installed, but not prepared for operation as tests were on the lower rotor only.

The internal busbars and connections appropriate to operation with the gas bearings and brushes were fitted, insulated and tested. A copper slip ring for the inner brushes and a high current joint of low melting point between ring and rotor were developed, made and fitted.

A large selection of instruments was fitted to the generator for observation, recording, control and testing of as many features as allowed by time and facilities.

The lower rotor was tested ultra-sonically and magnetically and closely inspected by other means for flaws and cracks and defects. No faults were detected.

The electrolytic load control system has been modified and improved to give greater reliability and more flexibility in programming current output of the generator, which was widely varied in the tests. A system of cycling the brushes known as "rupple pulsing" was designed, manufactured and used in the December tests. This allows the homopolar

generator to be operated at small currents over longer periods with greater efficiency and reduced brush wear.

With regular use of the homopolar generator in mind, following the development and testing of main design features, it is necessary to pay increased attention to the reliability, life and smooth functioning of all components and to reduce the probability of failure or even short shut downs. More consideration has been given to the detail engineering, the rapid detection of faults, protective action in emergencies, operational organization and a more comprehensive and automatic system of control instrumentation and recording. Lack of time, man power and resources do not allow all these to be fully studied, incorporated and brought up to a desirably high standard. The reduction of risks of failures and faults to negligible proportions and the avoidance of unscheduled shut down periods, entails, as usual in major, novel and complex machinery, great effort and time, and continual foresight, alertness and preparation.

High Field Magnets

Ultra-high magnetic fields, i.e., over 100 kilogauss, are at present in great demand for basic research particularly in solid state physics, though very few such magnets exist and none in Australia. Several laboratories abroad are extending their efforts to develop and operate magnets at fields of 150 kilogauss and higher, with usefully large volumes, homogeneity and duration. Development has been retarded for many years because of technological problems of strength and cooling and because the power requirements are beyond existing laboratory facilities and budgets.

The homopolar generator can provide far more than the necessary power in the form of pulses of usefully long duration. Preliminary investigations and advice led to the decision to use the homopolar generator for this purpose and preparations for magnet installation have been started. Negotiations for the design and production of a 150 kilogauss

magnet are under way and the feasibility of the development and manufacture of a 300 kilogauss magnet is also being studied, both here and in the United Kingdom in the interests of this laboratory. Design studies for magnet installation, control and ancillary equipment, such as cooling facilities are proceeding and building extensions are in progress. Some of the tests on the homopolar generator and electrolytic load were planned and performed in conformity with this program.

Negotiations for the supply of a helium liquefier from U.S.A. were completed and building plans for this installation prepared and submitted by a consulting architect. The liquefier considerably extends the value and range of research experiments in high magnetic fields and is also in demand by other departments in the A.N.U.

Plasma Physics

In 1963 it was proposed that the research activity of the Department be concentrated in plasma physics, and to have six to eight academic staff engaged on several lines of research which would be of intrinsic interest and value, but also appropriate to application of the homopolar generator when this was available for use. A nucleus of staff and equipment with well defined aims, interests and technology would then be able to select and critically evaluate both small and large experiments using the homopolar generator. However, expansion in this direction was restricted as a matter of policy and several proposed or already initiated developments and experiments were dropped.

With the return of Dr. A.H. Morton in October, 1964, from the Plasma Physics Laboratory, Culham, England, the plasma physics section now consists of three academics and two technicians. A further technician is to be recruited in 1965. In addition, there is one student taking a Ph.D. course, while up until the end of November, the section had a student visitor from the Moscow State University.

The work undertaken by the group has been both theoretical and experimental, although at the present stage of development, the latter

is probably best classed as engineering.

On the theoretical side, several aspects of plasma physics have been tackled. An analytical solution for steady state "runaway electrons" in a plasma has been obtained. Using Grad's thirteen moment approximation, the effects of inelastic collisions in a plasma have been investigated. The collision integrals associated with this problem have been reduced to workable forms, but due to the present lack of analytical expressions for inelastic differential cross sections, this work is not yet complete. However, work is continuing on this aspect of the problem and the indications are that adequate representations for these cross-sections will be found. An investigation of hydromagnetic interchange type instabilities has also been carried out, this being needed in connection with the proposed experimental programme. Finally, in association with members of the Ion Diffusion Unit, theoretical problems associated with space charge and secondary emission effects in Townsend type diffusion experiments have been investigated.

On the experimental side, the detailed design of a toroidal plasma machine began in June, 1964. The basic element of this machine, the toroidal vacuum vessel, has an aspect ratio of four to one, the minor diameter being 20 cms. The machine will be powered by a 10^5 joule condenser bank. This will be a highly flexible machine, but in its main mode of operation, it will behave as a pulsed Stellerator. Besides providing training facilities for students, the prime object of the machine will be an attempt to obtain a controllable plasma electron temperature over the range 10 to 100 e.V.

In its present stage of development, the major items of equipment for this experiment have been ordered, while several such items are already on site. It is hoped to have the machine operational by the end of 1965.

The section has not published this year, but five talks on current

progress were given at the Fifth Australian Plasma Physics Conference held at Lucas Heights in November, 1964.

Publications

A.N. Lebedev+ - "Particle Accelerators in the U.S.S.R." The Australian Physicist. Vol. 1, No. 5 (1964).

R.A. Marshall - "Tests with Solid Brushes on the Canberra Homopolar Generator". Nature, 204, 1079 (1964).

A.H. Morton - "Plasma in Mirror Machines". (U.K.A.E.A.) CLM-R-38. H.M. Stationery Office (1964).

+ Visiting Research Worker