the volume to surface ratio, the maximum error in the value is ± 14 per cent and the most probable error ± 5 per cent. This result supports Greening's interpretation of the residual current in ionization chambers at very low pressures. Although Greening did not claim a high degree of accuracy for his estimates, this measurement of the low-energy electrons emitted from the walls of an irradiated vacuum cavity chamber is in remarkably close agreement with his estimates.

We thank Mr. D. E. A. Jones for allowing us to use the radiation facilities at Mount Vernon Hospital, Northwood, and Prof. J. F. Fowler and Mr. J. Yarwood for their advice. This work was supported by the Department of Scientific and Industrial Research.

T. E. BURLIN
S. R. HUSAIN

Department of Mathematics and Physics,
The Polytechnic,
309 Regent Street,
London, W.1.

- ¹ Greening, J. R., *Brit. J. Radiol.*, **27**, 163 (1954).
- ² Klemperer, O., *Z. für Phys.*, **45**, 225 (1927).
- ³ Jaffe, G., *Ann. der Phys.*, **42**, 303 (1913).
- ⁴ Lea, D. E., *Actions of Radiations on Living Cells* (Camb. Univ. Press, 1946).
- ⁵ Trump, J. G., and Van der Graaff, R. J., *J. App. Phys.*, **18**, 327 (1947).
- ⁶ Cormack, D., and Johns, H. E., *Brit. J. Radiol.*, **25**, 369 (1952).
- ⁷ Taylor, L., *Brit. J. Radiol.*, **24**, 67 (1951).
- ⁸ Wilson, C. W., *Brit. J. Radiol.*, **27**, 158 (1954).
- ⁹ Sievert, R., *Acta Radiol.*, **21**, 189 (1940).
- ¹⁰ Burlin, T. E., *Brit. J. Radiol.*, **35**, 343 (1962).
- ¹¹ Burlin, T. E., and Husain, S. R., *Nature*, **204**, 563 (1964).
- ¹² Gray, L. H., *Proc. Roy. Soc., A*, **156**, 578 (1936).
- ¹³ Rep. Intern. Commission Radiological Units and Measurements. *Nat. Bur. Stand. Handbook 85* (1964).
- ¹⁴ Spencer, L. V., and Attix, F. H., *Radiat. Res.*, **3**, 239 (1955).
- ¹⁵ Burlin, T. E., *Phys. Med. Biol.*, **6**, 33 (1961).
- ¹⁶ Greening, J. R., *Brit. J. Radiol.*, **30**, 254 (1957).
- ¹⁷ Attix, F. H., De La Vergne, L., and Ritz, V. H., *J. Res. Nat. Bur. Stand.*, **60**, 235 (1958).

Tests with Solid Brushes on the Canberra Homopolar Generator

EARLY in 1963 a programme was begun with the view of establishing whether or not solid brushes could be used instead of liquid metal jets to collect the required current (1.6 million amp) from the rotors of the Canberra homopolar generator. Within the first few weeks of investigation it became clear that there were no insuperable problems. Many pilot tests were conducted and details of the design will be published later. Since then, brush gear has been designed, manufactured and installed, and large-scale tests have been made with this gear in the homopolar generator. The behaviour of these brushes has been very satisfactory.

The homopolar generator was designed to produce a roughly sinusoidal current pulse lasting for nearly 2 sec with a peak of 1.6 million amp. In the initial tests¹, this current was drawn from the rotors by means of sheet jets of sodium-potassium alloy. The brushes have been designed for the same duty as the NaK jets, namely, to carry 1.6 million amp from the rims (outer brush units) of the mild steel rotors, at a rubbing speed of up to 33,000 ft./min. The inner brush units were designed to take the same current from an auxiliary copper slip ring clamped to the rotor, with a rubbing speed of 11,000 ft./min. Both sets of brushes were required to carry current for about 2 sec.

The arrangement of the generator for these tests was different from that used for the initial tests. The lower rotor was used, the upper rotor being clamped. The inner brush units were bolted to contact blocks which, in turn, were bolted to copper segments clamped to the bottom pole face. The outer brush units were bolted to an annular copper ring around the rotor and were staggered to run on a band 2.5 in. wide on the rotor rim. Both sets of brushes

were brought into contact with the rotor for the duration of the pulse only, this being done by means of compressed air. A complete outer brush set consists of 864 brushes of 1 cm² arranged in 72 units. Thus the peak current per brush is 1,850 amp. The inner set consists of 576 brushes, 2 cm thick by 0.5 cm wide, arranged in 36 units, the peak current in each brush being 2,780 amp. The brush material is a standard high copper grade (Morganite CM1S). The brush wear-rate appears to be about 0.0001 in. per pulse for the outer brushes and about one-twentieth of that for the inner brushes. The load holding each brush on to the rotor rim and slip ring was 8 lb. The contact voltage drop between the outer brushes and rotor was about 0.75 V at peak current, the inner ones being half this.

In order to facilitate tests, the decision was made to install only one-half on each set of brush units and proportionately to decrease peak current to 0.8 million amp. Maximum surface speed of the rotors used was 22,000 ft./min.

Fig. 1

During the tests, 137 current pulses were taken, 30 of which had 0.8 million amp peaks. Further, of these 30, four were taken from an initial rotor surface speed of 22,000 ft./min, and another 21 taken from an initial speed of 17,000 ft./min. The shape of the current pulses and the corresponding outer brush actuating air pressures are shown in Fig. 1. During these tests the machine and all its ancillary equipment functioned well for a total running time of more than 50 h. There has been no sign of damage to the brush track on the rotor rim so far.

The appearance and performance of the homopolar generator with brushes is clean, neat and impressive. These tests have demonstrated that large energy stores of this type are a safe practical engineering proposition, at least up to the conditions of the tests and probably up to the full design conditions. Life tests on the generator are continuing.

I thank Sir Mark Oliphant and my colleagues and the technical staff of the Brush Group for their help and advice.

R. A. MARSHALL*

Research School of Physical Sciences,
Institute of Advanced Studies,
Australian National University,
Canberra.

* Present address: c/o Large Generator and Motor Department, General Electric Co., Schenectady, New York.

¹ Blamey, J. W., Carden, P. O., Hibbard, L. U., Inall, E. K., Marshall, R. A., and Oliphant, M., *Nature*, **195**, 113 (1962).

GEOLOGY

Some Radiometric Rock Ages and the Problem of the Southward Continuation of the East Greenland Caledonian Orogeny

THE work of Lauge Koch and others has established that a powerful Caledonian orogeny occurred in what is now the coastal region of East Greenland, north of Scoresby Sound. Whether this orogenic belt continues down the east coast of Greenland and joins the Caledonian mountain