either cellulose acetate or nylon film, no evidence was found of twin peaks with these dyes deposited on quartz, but instead just a general absorption band somewhere between 5100 and 6500 A. All these three dyes on quartz exhibit a very marked absorption maximum in the neighbourhood of 2500 A.

Absorption spectra were measured on a Unicam *SP*500 quartz spectrophotometer.

G. S. Egerton
A. G. Roach

Department of Textile Chemistry,
Faculty of Technology,
University of Manchester.
Dec. 11.

Variable-Energy Particle Accelerators

Considerable interest has recently been shown in the heavy-particle, and in particular proton, accelerators that are capable of delivering, with a narrow spectrum, a wide range of output energies. Interest has been focused on two ranges of proton energies: 3–15 or 20 MeV. and 3–50 MeV., with an easing of the requirements concerning permissible width of spectrum at the higher energies.

For the lower range, two 6-MeV. Van de Graaff generators, operating in tandem, have been proposed. Negative ions would be accelerated through the first generator and then stripped, by passing through a foil, and accelerated as protons, through the second generator, to the final energy.

An alternative proposal is to design a special cyclotron employing a large magnet and low magnetic field-strength[1]. This design, based on the work on the Medical Research Council cyclotron, aimed at achieving the specified narrow spectrum by a rigid control of the accelerating voltage, magnetic field-strength, etc., and restriction of the phase-width of the beam near the region of the ion source[2].

For the higher energy-range, a proton synchrotron has been proposed, incorporating Prof. P. B. Moon's suggestion[3] for increasing the beam current by injecting molecular ions (H_2^+) into a static, or nearly static, magnetic field and dissociating them into protons by passage through a gas.

An examination of the relationship between pitch and phase velocity for a helical wave-guide (Fig. 1) shows that, for a given pitch, the phase velocity varies with the frequency of the input power. It has been suggested[4] that this fact might be utilized for constructing a variable-energy helical wave-guide accelerator[5]. It is likely that such an accelerator would possess a sufficiently narrow spectrum, and the absence of extraction problems and accessibility of the input give a decided advantage over the synchrotron and cyclotron. The maximum energy of 50 MeV. or greater also gives it an advantage over the Van de Graaff machine. As with all types of linear accelerator, the output intensity would depend largely upon the degree of success that attended the solution of the focusing problem.

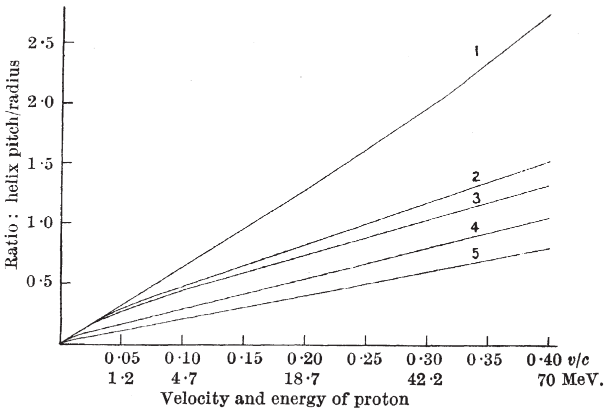

Fig. 1. Curves for various values of ratio a/λ: (1) 1·0; (2) 0·015; (3) 0·010; (4) 0·002; (5) 0·0002; where a is helix radius and λ the free space wave-length

The curves of Fig. 1 have been plotted using the sheath theory[6], and it will be observed that, for the higher frequencies, the region over which the curves depart from linearity is somewhat larger. It follows that the conditions governing phase oscillation will vary with frequency and may lead to loss of beam current. Whether the more exact tape theory[6] shows greater or less linearity is being investigated, but the qualitative solution of the problem is to use as high an injection energy as possible.

These considerations assume that the accelerator is rectilinear and employs, say, the strong focusing system suggested by Blewett[7]. For the spiral accelerator put forward by Sinelnikov *et al.*[8] and me[9], the conditions are more stringent; for without variable magnetic shimming it is necessary that the pitch versus phase velocity relationships be of the form of straight lines passing through the origin. From Fig. 1, it may be seen that this is approximately true for the range $2 \times 10^{-4} < \alpha/\lambda < 2 \times 10^{-3}$. The use of variable magnetic shimming is, of course, not impossible, but it introduces an unwelcome complication.

The spiral accelerator utilizes the transverse electric forces of the electromagnetic wave, that are normally defocusing, as focusing forces, in addition to those produced by the constant gradient magnetic field. The defocusing forces are therefore those due to space charge, inhomogeneities in the magnetic field, gas collisions and, indirectly, those due to errors in construction. These are present in both the rectilinear and spiral accelerators although the errors in construction are likely to be greater in the latter.

In the light of this new interest in variable-energy output, it may well prove profitable to re-examine the engineering feasibility of wide-band travelling-wave structures such as the helix.

My thanks are due to the Medical Research Council and the National Research Development Corporation for sponsoring this work and for permission to publish this communication.

J. W. Gallop

National Research Development Corporation,
1 Tilney Street,
London, W.1.
Dec. 7.

[1] Gallop, J. W., Vonberg, D. D., Powell, W. B., and Waterton, P. J. (private circulation, March 1956).
[2] Powell, W. B., *Nature*, **177**, 1045 (1956).
[3] Moon, P. B., Proc. C.E.R.N. Symposium in High-Energy Accelerators and Pion Physics, **1**, 231 (June 1956).
[4] Patent Application No. 20925/56.
[5] Walkinshaw, W., and Wyllie, K., *AERE/TRE* Maths. Memo./57/*WW* (1948).
[6] Sensiper, S., *Proc. Inst. Radio Eng.*, **43**, 149 (1955).
[7] Blewett, J. P., *Phys. Rev.*, **88**, No. 5 (1952).
[8] Sinelnikov, K. D., Fainberg, Ia. B., and Zeidlits, P. M., Proc. C.E.R.N. Symposium on High-Energy Acceleration and Pion Physics, **1**, 215 (June 1956).
[9] Gallop, J. W., *Nature*, **171**, 306 (1953).