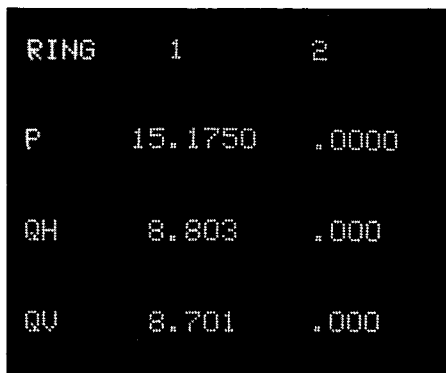




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eliminated and the flux variation in the coil deduced directly as $V_r \times t$.

Automation of the operation and processing of the information has been made possible by the use of a computer (Hewlett Packard model 2114). It is programmed :

- to control the various measurement sequences ;
- to read the counters and calculate the final values ;
- to display the results on a cathode ray tube in the Control Room (and in the Reference Unit Room) ;
- to transmit the results to the ISR central computer.

As well as the various parameters (surfaces and resistances of the coils, carriage strokes, reference voltages) needed in the measurement procedure, the memory of the 2114 computer also contains the average results of the magnetic measurements made on all the ISR units. On the basis of measurements in the reference units, it is capable of calculating the behaviour of the entire rings. The display in the ISR control room shows either the magnetic characteristics of each ring (bending and focusing parameters) or the related beam parameters :

- the momentum corresponding to the central orbit ;
- the vertical and horizontal betatron oscillation frequencies ; (Q_v and Q_H are calculated with variation formulae drawn from experimentation with the ISR).

The rate of measurement is essentially limited by the time required for the movement of the coils (60 s for a complete measurement).

Further facilities have recently been added to the system to allow a rapidly varying field to be measured. The voltage induced in the measuring coils (which in this case remain stationary) is converted into a frequency and the field variation is displayed in the form of an index moving along a graduated



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scale. The first stage of the computer-controlled sequence includes the automatic compensation of the integrator drift.

This monitoring system, built by the Magnet Group, has been extensively used since the beginning of tests on the ISR. It gives a direct, fast and extremely accurate indication of the magnetic characteristics of each ring.

200 mA from 3 MeV

The 3 MeV experimental linac accelerated a proton beam (analysed) of over 200 mA for the first time on 12 May — the peak current which has been achieved is 215 mA.

The big beams, whose energy spread and emittance have not yet been studied, came after changing the 18 focusing quadrupole settings in the linac tank (to operate in the $+ - + -$ mode rather than $++--$ as in the 50 MeV linac of the proton synchrotron). The last 20 μ s of 100 μ s pulses of protons from the 500 keV preinjector were selected for acceleration; these corresponded to the most stable part of the preinjector pulse. The modifications which brought about the high currents could not be translated directly to the PS linac where the quadrupole cooling is not as efficient as on the small experimental linac. The pressure at the PS linac is, in any case, to deliver 100 mA in 100 μ s pulses ready for the coming into operation of the 800 MeV Booster and the 3 MeV linac has been helping by studying long pulse effects in the preinjector region. (The preinjector on the experimental linac is the same as on the PS linac.)

In fact the recent push to high currents came as something of an interlude in the midst of a difficult study of space charge effects in low energy beams. Here computations predict that the space charge forces (where the positive charges on the protons

Photographs of ISR magnetic field parameters as displayed on a TV screen.

1. With just Ring 1 in action the magnetic field is set to that corresponding to a proton momentum 'p' of 15.175 GeV/c and horizontal and vertical betatron oscillation frequencies of $Q_H = 8.803$ and $Q_V = 8.701$.

2. Rapid field variation is displayed in the form of an index moving along a graduated scale. The initial field, which corresponded to a proton momentum of 11.6244 GeV/c, has been changed by approximately ± 0.02 T.

are pushing away from one another giving a 'blow up' of the beam) have a considerable effect on the beam behaviour.

Initially one aim, working with the 500 keV preinjector beam, was to remove the space charge effect by controlled neutralization, injecting electrons into the beam to cancel out the positive charges on the protons. But this has proved very difficult to master mainly because the proton beams have been shown to be neutralizing themselves without any help ! This was evident from the fact that theory and experiment did not line up and beams of much higher current than calculated could be transported.

The self-neutralization appears to be coming from two sources — from ionization of residual gas which yields electrons, and from particle loss (protons and other ions) to the metallic walls which liberates electrons. At first sight it seems nice to be getting required neutralization for free but the trouble is that self-neutralization is not easily controllable. The degree of neutralization is difficult to predict and the electrons are of low energy (a few eV, for example) and hence easily disturbed, by imposed focusing fields or biases, abruptly changing the space charge property of the beam.

The implications of these findings for the PS linac are being considered and will probably result in reorganization of some of the focusing at the low energy end in such a way that space charge or beam neutralization is not a dominant influence on the beam behaviour and reproducibility.

The availability of the 3 MeV linac is making it possible to carry out more detailed studies on high intensity, low energy proton beam behaviour than has ever been done before. Generally, a linac is swept into action to feed a synchrotron, leaving little time to get to know the beam well.