Rutherford Laboratory

Technical Leaflet

A5

THE NIMROD MAGNET

The charged protons will follow a curved path in a magnetic field. Each time they circle the magnet ring they are given a kick of extra energy in an r.f. cavity (located in Straight Section 8) and their increased energy would tend to move them onto an orbit of greater radius. To counter this, the magnet field rises as the energy of the protons increases. The actual paths of the protons are oscillations about their mean orbit and to keep the beam stable it is necessary to have the magnetic field increasing with radius across the magnet gap. The maximum possible aperture inside the vacuum vessel is required to accommodate the oscillations so that the maximum number of protons are 'accepted' and accelerated.

The magnet is in the form of a ring about 150 ft. in diameter, containing about 7000 tons of steel in the yoke with 350 tons of copper conductors. The ring is composed of eight curved sections (Octants) separated by short straight sections which are relatively field-free. These straight sections enable essential components to be readily installed. In vertical cross-section the magnet yoke is C-shaped, with a 9 in. vertical gap 36 ins. wide, available as acceleration space.

An octant is made of 42 'sectors', each of which is just over a foot thick and 10ft. 5ins. in height. The sectors are themselves composed of $\frac{1}{4}$ in. steel plate laminations to reduce eddy currents during the magnet pulse. During acceleration the field rises to 15000 gauss in 0.7 secs, the pulse repetition rate being about one per two secs. In order to avoid variations in the magnetic field around the ring due to variations in sector quality, the sectors were measured magnetically as they arrived, and were assigned positions round the ring which would give a high degree of "randomness" in any variation.

The change in field across the magnet gap is controlled by specially shaped polepieces on each sector. The polepieces are made from much thinner steel plate laminations than the sectors, about 400 plates to each polepiece. The profiles of the plates were chosen by a series of experiments on magnet models and four different profiles are arranged in a repeating sequence in the polepiece. This controls the saturation of the laminations and maintains the desired field gradient in the region occupied by the beam at any point during the acceleration. To ensure stable circulation of the beam the magnetic field must be changed by about 1% per foot radial displacement, and this must be accurately maintained as the field rises during the magnet pulse. The polepieces are also designed to bring about an economy in the total flux handled by the magnet at peak field.

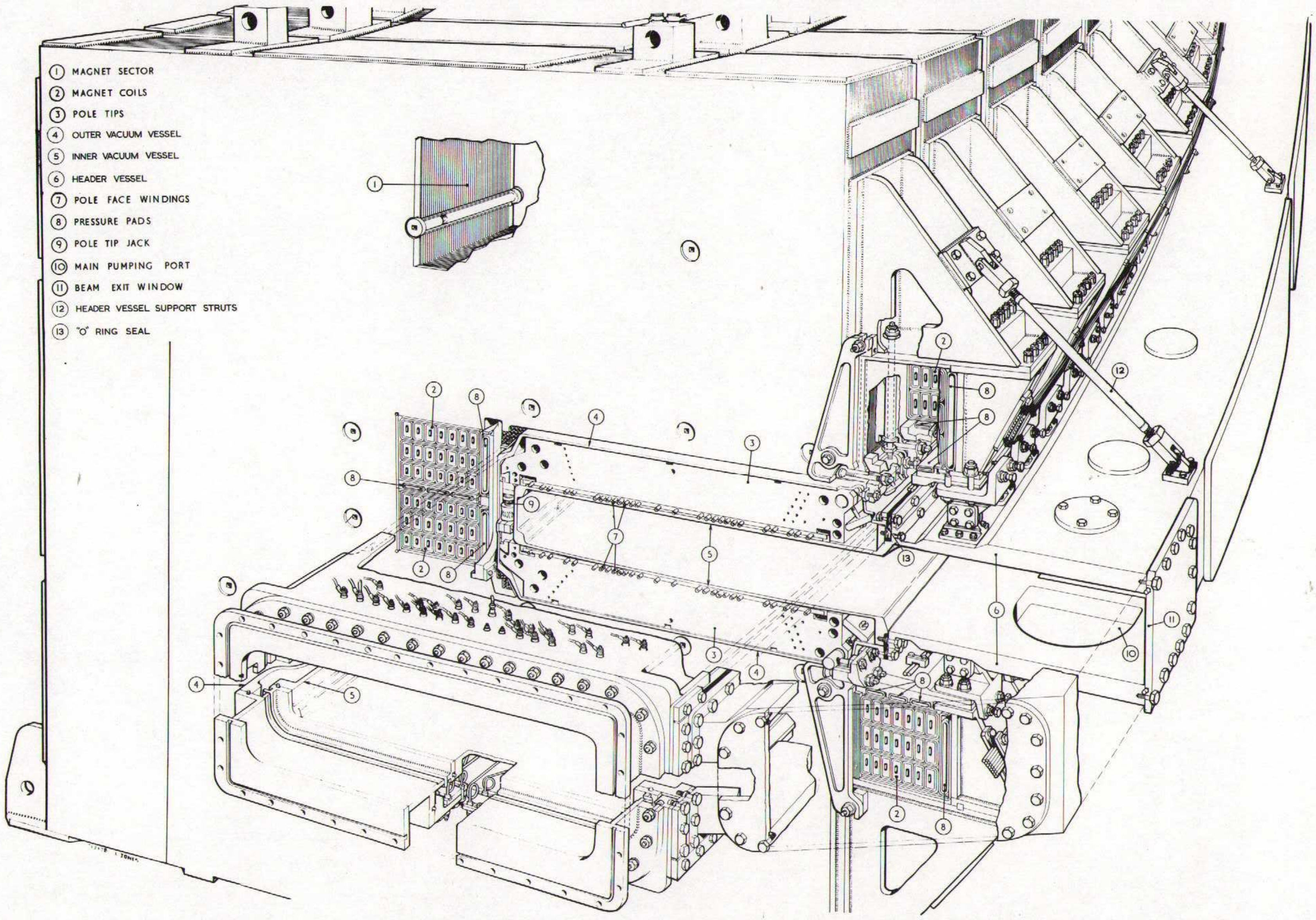
At the ends of each octant, special polepieces prevent the magnet field penetrating far into the straight sections and determine the effective magnetic length of the octant, which must remain substantially constant during the magnet pulse.

On the polepiece surfaces, several conductors run the length of the octant. These are known as pole-face windings and they can be powered during the acceleration cycle to correct any minor defects in the field.

Each octant is energised by two coils, of 42 turns. These conductors are curved, hollow, copper bars (1.375 in. by 2.625 in.) through which flows demineralised cooling water. The power dissipated by the whole magnet is about 3 MW. The peak current is 10,500 A, which gives a magnetic field of 15 kgauss and the peak stored energy in the magnet is 40 Mjoules. To give the required rate of field rise a total voltage of 16 kV is applied. The simultaneous requirements of adequate electrical insulation and of clamping to withstand the large mechanical forces between conductors, posed a considerable problem.

Any errors in the positioning of the sectors is reflected as a loss of effective aperture available for acceleration, and one can calculate the price paid, inch for inch, for various misalignments. A particularly severe requirement is that the sectors shall not be tilted in their own vertical plane; 10 seconds of arc tilt costs about 0.3 ins. of vertical aperture. The problem of alignment required the best surveying instruments available.

After the magnet had been carefully aligned a magnetic survey was carried out in 1962. This checked, amongst other things, the symmetry of the magnetic field to a few parts in 10^4, the height of the magnetic median plane and the field-shaping effect of the polepieces. The survey relied chiefly on search coils, induced voltages during the magnet pulse were recorded on magnetic tape and directly processed by a computer.



PICTORIAL VIEW OF TYPICAL CROSS SECTION THROUGH MAGNET OCTANT OF "NIMROD"