

Nimrod's Protons Contained by Glass Fibre

In choosing plastics for Nimrod's vacuum vessels the Rutherford laboratory was committed to one of the largest, most complex accurate structures ever built in this way.

IN DESCRIBING Nimrod, the proton synchrotron at the Rutherford High Energy Laboratory, Harwell, last week as a research topic, **ENGINEERING** stated that the toroidal vacuum chamber was one of the most difficult tasks in the construction of the installation. Requirements of the material used for the vacuum vessel were that it was non-magnetic, non-conducting and as thin as possible. Eddy currents and any more than minimal gas evolution could not be tolerated, vacuum maintenance to the order of 5×10^{-4} torr litres/sec was necessary and it had to be unaffected by any stray particles. Extensive research was carried out into the properties of a variety of possible materials and glass fibre, reinforced with CIBA Araldite epoxy resin, more specifically Bisphenol "A" diepoxide, was finally chosen.

The purpose of the machine is to produce a proton energy of 7 GeV of high intensity, 10^{12} protons per sec, higher than the larger 25 GeV machine built by CERN in Geneva which has a complementary function. The machine consists of a magnet ring 155 ft in diameter built in eight circumferential sections and containing 7,000 tons of special magnet steel. Within the magnet gap, 36 in wide and 9½ in high, is the vacuum vessel in question, divided into octants each 49 ft in length.

The principle of operation is to extract protons from an ion source, focus them into a beam and admit them to a linear accelerator which raises their energy to 15 MeV, that necessary to ensure an orbit of the required radius when they enter the annular vessel. Once in the vessel the protons are accelerated once each circuit by a radio-frequency accelerating system in increments of about 7 KeV each time. After some one million circuits, the protons have reached a velocity just below the speed of light and are extracted from the machine and thence through channels in a 30 ft concrete wall where the research equipment is installed.

Epoxy resins were chosen as the material for the vacuum vessel as they have been found to provide a combination of properties not found in any other resin system. They have excellent adhesion to other materials, low shrinkage on cure, do not evolve by-products whilst curing and can be formulated to possess good irradiation resistance.

Phenolic resins fall short of the requirements since both high and low pressure laminates show hydrophilic characteristics (70-100 mg to BS 972). This will cause high outgassing rates due to desorbed water. Polyester resin systems are versatile and easily tailored to a specific purpose. They are, however, inferior to epoxies in respect of outgassing, irradiation resistance and shrinkage on cure.

Melamine-formaldehyde polymers, correctly handled, will produce good laminates but again irradiation resistance is not good and the rate of gas evolution high. On the other hand silicone based laminates have good gas evolution characteristics and satisfactory irradiation stability. They were, however, discounted on the grounds of production and handling difficulties.

Glass fibre reinforcement was chosen as none of the possible alternatives—organic monofilaments of polyester, nylon, rayon, etc.—possessed adequate strength properties. Leakage was found in early test laminates and traced to the existence of hollow fibres in the glass cloth. Techniques were evolved to prevent fibre ends from being exposed.

The vacuum vessel consists of three main components and is double-walled within the

magnet gap. The outer vessel has a thickness of only 3 mm being supported by the pole tips which are jacked apart at the back of the magnet throat and bolted through vacuum seals to the coil brackets. Its purpose is to reduce the atmospheric loading on the inner vessel which as a result has only to support its own weight. Thus its relatively thin walls, 6.4 mm, consume a minimum of space within the magnet gap. The header vessel, on the other hand, connecting the inner vessel with the vacuum pumping system, is subjected to full atmospheric pressure and is up to 2 in thick.

The high vacuum surfaces of the inner and header vessels are lined with 4 in wide strips of stainless steel foil 0.002 in thick. This lining improves the vacuum properties of the laminate and prevents accumulation of electrostatic charges; but small gaps are left between adjacent strips to reduce the danger of eddy currents.

Marston Excelsior Limited, of Wolverhampton, have been responsible for the construction of the vessels. Some of their extreme difficulties in maintaining the very close tolerances in the inner and outer vessels were outlined in **ENGINEERING** (24 Aug. '62, p. 248). One persistent leak was traced to the intrusion of a human hair on to the laminate.

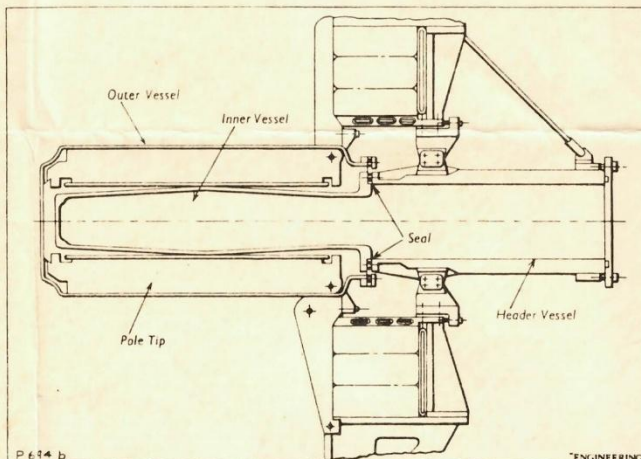
Each octant of the outer vessel was built in three parts, each third laid up on a curved die bed containing 21 dies; one die giving the correct profile for a length of 35 cm. A controllable means of heating and cooling was provided for individual dies and a limited length of the bed covered by punches, similarly equipped, and able to move along the bed as manufacture progressed. The die was first coated with a release film and the resin-wetted mat laid up by a technique involving rolling the laminate

through a barrier film of polyester to ensure that air inclusions were brought to the surface. Mating sections were left with "wet" edges, i.e. kept cool so as to delay full curing of the resin until the components had been spliced together. Water along the edges of the matched tools was used as the cooling medium.

The complete vessel side was assembled by laying sections with opposite handed flanges on extensions to the die bed and laying up the middle third in between. Two sides so produced were then spliced on a special ring equipped to form the two end flanges and the dorsal wall. The inner vessels were similarly formed using a different die bed, the steel foil being laid on the laminate prior to pressing and curing.

A different approach was made to laying the header vessels; they are thicker and tolerances wider. Time was saved and strength maintained by a sandwich construction with outer layers only of 0.006 in cloth while the bulk comprised 0.017 in cloth interspersed with the thinner cloth.

In 1962 a Harwell spokesman said the laboratory was reluctant to select a non-metallic structure. Experience, however, has shown that glass fibre has many characteristics that are essential in these conditions. Since then, too, experience in the USA at Argonne Laboratories has shown that stainless steel racetracks, as used on the Zero Gradient Synchrotron, have their problems, as the thin sections necessary have poor stability under vacuum loading.



(Right) Section through the Nimrod vacuum vessels.

(Below) Part of the inner vessel being installed in the magnet throat.

