Rutherford Laboratory

Technical Leaflet

A5.4

NIMROD VACUUM VESSELS

The manufacture of the vacuum vessels was one of the most difficult tasks undertaken in the construction of NIMROD. A great deal of development work was involved before a satisfactory vessel could be produced. Many resins and manufacturing processes were evaluated so that the best combination of qualities such as outgassing rate, irradiation resistance and mechanical strength could be obtained, consistent with manufacturing feasibility.

The materials finally chosen were Bisphenol 'A' diepoxide resin cured with methyl 'Nadic' anhydride and reinforced with glass cloth.

Each vessel is over 50 ft long subtending an arc of 45° on a 60 ft inner radius.

For reasons of convenience and economy each vessel was fabricated from a number of pieces. These pieces basically units of one third of the length of a vessel side are shown in Fig. I.

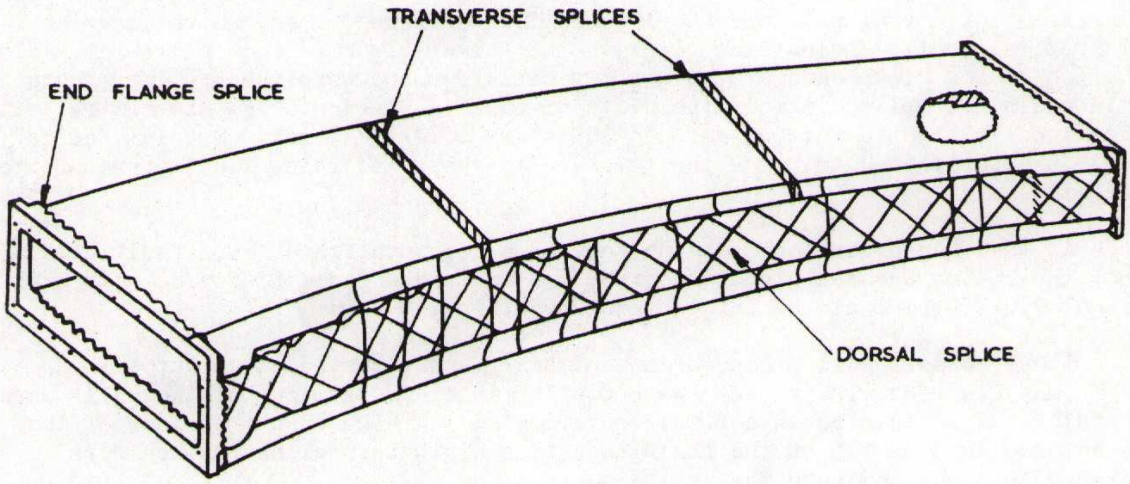

FIGURE 1.

Each third of a side was produced by laying up glass cloth and resin on a curved die bed approximately 20 ft. long and 5 ft. wide. Individual dies were 14 inches wide and provided with controllable means of heating and/or cooling. A limited length of this die bed could be covered by punches with similar heating and/or cooling facilities. These punches were moved stepwise along the bed as manufacture of the laminate proceeded.

Glass cloth was pre-impregnated with resin and allowed to soak for 24 hours. Lengths were then cut and laid along the die bed, alternate layers being placed diagonally to give more uniform strength to the finished laminate. Additional resin was added during the process and every few layers the laminate was rolled to force out air bubbles trapped between the cloths and to consolidate the lay up. Pre-fabricated, semi-cured (or 'B' Stage) packs, specially shaped to form the main vacuum flange and dorsal shoulder were positioned on the outer and inner circumferences of the die bed and retained by the boundary layers of glass cloth. For an outer vessel further cloths were added to the laminate at one end of the die bed to increase the thickness to 1", the remainder of the area consisting of 20 layers of 0.006" cloth. Punches were then positioned and a portion of the lay up cured by heating. To facilitate subsequent processes, where the edge of a laminate was to be joined to another component by splicing, that edge of the punch and die was cooled so that the uncured resin could in fact be washed out of the protruding cloths by solvents. This allowed the fabricated sections to be stored indefinitely.

The next third of a side was manufactured similarly but with the thickened portion at the opposite end of the die bed. A complete vessel side was then formed by laying these two opposite handed sections on extensions to the die bed. The protruding cloths from the ends were re-impregnated with resin and interleaved with new cloths laid on the die bed to form the centre section of the side and this portion cured by the same stepwise movement of punches and temperature cycling as before.

After two such sides had been produced they were spliced together on a special rig where the dorsal wall and the two end flanges were formed. Each side was clamped vertically against the rig with the larger circumference nearest the floor. The protruding cloth ends at the smaller circumference were then re-impregnated with resin and spliced across the width of the rig, beginning at the centre, with additional cloths to form a laminate 30 layers or 3/16" thick. Special tools were then positioned to press the laminate to shape and raise its temperature to cure it.

At the ends other tools in the form of a "picture frame" were positioned so that the re-impregnated cloth ends from the two sides could be formed with additional 0.017" thick cloths into a flange 2" thick.

Inner vessels were produced in a similar manner to the above but with a different die bed. The vessels were smaller in cross section but the walls were $\frac{1}{4}$" thick. The stainless steel foil covering on the high vacuum surface of the vessel was laid on top of the resin and glass cloth before the punches were lowered to press and cure the laminate.

The header vessels required a slightly different approach since they were mainly 2 inches thick. To maintain strength of the laminate while shortening the lay up time, only the outer layers on each side were wholly of 0.006" cloth, the bulk of the laminate consisting of 0.017" cloth interspersed with 0.006" cloths every seven layers to reduce resin drainage to the bottom of the laminate.

The inner flange rail on the moulding bed was fixed but the outer flange rail was sectioned and components made interchangeable to permit the contour to be varied for each third of a side. The differing thicknesses of the laminate necessitated an assembly of metal shoes and plates to form the correct contour. The shoes were fixed to loading arms stretched between inner and outer flange rails.

After lay up, the whole moulding bed was moved on a wheeled trolley into a gas-fired oven for the curing schedule. The technique of splicing components to form sides and then vessels was similar in principle to that for the other vessels. Selected sides were machined to provide the apertures for the pumping ports on the completed vessels.

Each vessel was exhaustively tested for vacuum leaks after delivery to site. All vessels had to be tested before installation in the magnet to avoid difficulties of testing and repair due to inaccessibility. This required the design and construction of special rigs and internal supports. Test and repair techniques were developed on a prototype vessel and led to the improvement of manufacturing processes on subsequent vessels.