MECHANICAL DESIGN OF A DELAY LINE FOR THE ASTRON LINEAR ACCELERATOR BEAM TRANSPORT

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Summary

The Astron concept for Thermonuclear research requires a layer of circulating electrons of sufficient density to confine and heat a plasma[1]. This layer, called the E-layer, is formed by an accelerator injecting 6 Mev electrons at a 4° angle from perpendicular. The accelerator[2] produces a 600 amp pulsed beam of 300 ns duration.

A delay line has been built for the purpose of increasing the peak injection current[3]. The 300 ns pulsed beam is split in half by a kicker and the first half is delayed so it can be injected on the opposite side of the trapping solenoid simultaneously with the second half of the beam. Thus two short pulses of 150 ns each are injected into Astron with one pulse traveling through a transport system of five bends and straight sections[4]. (Figure I).

General Description

Useful space was limited to an aisle alongside and parallel with the accelerator. This constraint led to the odd shape of the delay line.

The beam is bent on a 7° angle into the delay line with the following half kicked straight ahead. The first half travels 60 in. and then enters a 4 in. I.D. pipe which is covered by a pulsed air core, air cooled, dipole magnet, with a 24 in. bending radius and a bending angle of 173°. Superimposed over this is a pulsed quadrupole magnet. A conductive shield surrounding this protects the straight through beam from magnetic disturbance.

This bend transports the beam upward and to the right on an angle 40° from horizontal so when it emerges it is going straight in the opposite direction alongside the accelerator. The first straight section, approximately 50 ft. long, consists of a continuous solenoid surrounding an 8 in. vacuum pipe. It is constructed of .467 in. square hollow copper conductor wound on a 10 in. diameter aluminum tube which serves as a permanent support for the internal vacuum pipe. The 7 ft. and 3 ft. long coils are wound in two layers of opposite helix pattern to eliminate net axial flow. Each layer is a separate electric and hydraulic circuit element with coils powered in series and cooled in parallel. The end connections are made so the coils butt together to minimize dipoles. The end magnets of the straight section are powered individually as focus elements.

The second and third bends direct the beam forward again. Each coil bends the beam 90° on a 24 in. radius. Air core, water cooled, dipole and quadrupole coils surround an 8 in. I.D. vacuum pipe. Between bends is a quadrupole triplet for x-y focusing.

Another straight continuous solenoid carries the beam into the Astron experimental area and into the last bends which are identical to the previous bends with the exception of an 8° rotation coil located over the center quadrupole to adjust for the helix bend prior to injection into Astron.

For steering, coils are located at the entrance and exit to each bend. These are made of wire wound on a plane of .032 thick G-10 epoxy laminate sheet. When wrapped around the continuous solenoid, the conductor wires are in a cosine distribution.

Bending Magnets, Figure II

These magnets are constructed by placing .250 in. square hollow conductors around the cross section of a torus in a modified cosine distribution similar to the magnet construction on the high intensity storage rings[5]. Each conductor carries the same magnitude of current. The cosine distribution is determined by subdividing the area under the cosine θ curve into a number of equal area segments with a conductor then being placed at the center of each segment. The curvature effects of the torus requires the position of the conductors to be shifted from the cosine distribution, to get a uniform field. Forty conductors are held in position by bakelite rings, which are glued to the torroidal vacuum tube. Four parallel water circuits are required for cooling.

The quadrupole magnets are constructed the same way with the cosine 2θ distribution being modified. These are superimposed over the dipole magnets.

Vacuum System and Supports

Where the beam transport is straight, each section of vacuum pipe and magnet are a subassembly with the vacuum pipe supported within the magnet on rollers. Two wheeled dollies are clamped with bands to each end of the magnets. Tracks for the dollies consist of a 6 in. aluminum wide flange section on edge. Each section is installed at one station and rolled along the track to their final position.

Four 6 in. mercury diffusion pump units stationed along the line evacuate the 8 in. pipe to a pressure of 10^{-6} to 10^{-7} torr. Each unit is connected to the vacuum pipe by a manifold having a pumping speed compatible with the system, yet leaving only a 2.5 in. gap between the transport magnets. Aluminum foil gaskets are used in the vacuum pipe to eliminate gasket damage due to radiation, thus minimizing maintenance.

References

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Work performed under the auspices of the U.S. Atomic Energy Commission

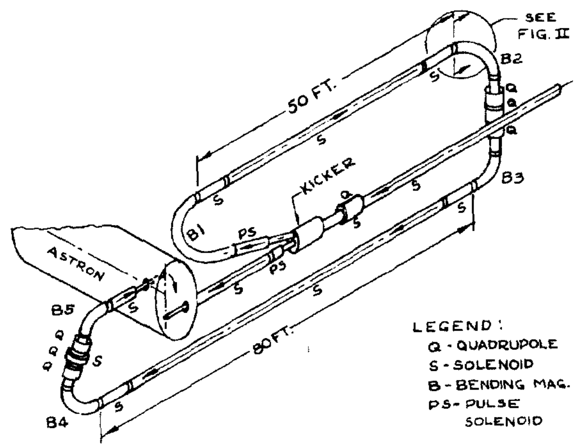

Figure 1.

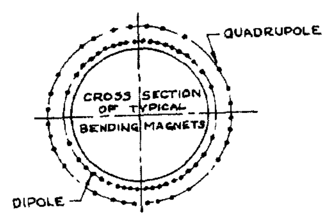

Figure 2.