PLUNGING FARADAY CUP SYSTEM AND A SLIT SYSTEM FOR USE IN THE ZERO GRADIENT SYNCHROTRON SHORT STRAIGHT SECTIONS*

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Summary

Each short straight section of the Zero Gradient Synchrotron (ZGS) contains mechanisms for positioning three beam detectors. The mechanisms are noteworthy because of their unique target fast stroke length adjustment capabilities.

One detector consists of a solid plate containing a long, horizontal slit. Plate position is vertically adjustable over a wide range. Beam currents to the plate flow through a coaxial cable to a signal detecting circuit.

The second detector is a vertical square bar that is plunged upward. The plunge distance and horizontal position of the bar are continuously adjustable over the whole aperture. A coaxial cable connected to the bar carries beam currents to a signal detecting circuit.

The third device is a vertical segmented assembly of linearly arranged detectors that can be plunged downward. The plunge distance and the horizontal position of the segmented assembly are continuously adjustable over the whole aperture. Each insulated segment is connected to resistor networks that provide voltages proportional to the total current to the segments and to the weighted function of the current to each segment. The vertical position of the beam can be derived from these voltages.

Introduction

The unique detector mechanism is a beam interrupting device for use in the study of beam characteristics. One mechanism is located at the upstream face of each of the four downstream short straight sections, 90° apart azimuthally. Each of the mechanisms consist of three members for examination of the beam as follows: 1) a vertically adjustable solid horizontal plate extending across the chamber, 2) a nonsegmented solid square vertical detector, and 3) a segmented assembly of detectors linearly arranged to read beam vertical position and distribution. The second two devices are radially adjustable and can be plunged into or removed from the beam aperture in about 100 milliseconds. The depth of encroachment of any of the three devices upon the beam aperture can be slowly and independently varied up to a maximum of five inches. The thickness of the detector is adequate for stopping the beam up to 100 MeV in energy. At higher energies, the beam is clipped so as to leave the accelerator rapidly. All drives and feedback components, except some limit switches, are outside the vacuum chamber resulting in minimum radiation exposure.

Design Requirements

The initial requirement was to design a mechanism which provided three independent beam detecting devices for installation and operation 90° apart azimuthally around the accelerator ring and located in the short straight sections. The mechanism was to have a solid horizontal plate with sufficient height and length to block the beam aperture. The plate was to be vertically adjustable with the capability of being stored either above or below the chamber opening.

A 1/2-inch square aluminum target for vertical insertion into the beam aperture was the second detector requested. This member was to be radially positionable and capable of fast insertion and removal from the aperture. The length of the insertion stroke was to be selectable up to a maximum of 5 inches.

The third required member was a segmented assembly of seven 1/4-inch wide by 9/16-inch high targets linearly arranged in a vertical detector. This detector was to have the same versatility as the nonsegmented aluminum member.

Investigation of the short straight sections revealed that electrode assemblies were present which essentially consumed all the azimuthal space available inside the section. Actual measurement placed the electrodes within 2-3/8 inches of the azimuthal walls. Furthermore, observance of the electrode installation reveals that the end of the electrode guard frequently contacted the walls when insertion or removal was required. With these existing conditions, it was established that the required mechanism had to be held to a maximum thickness of 2-1/4 inches, including targets, and that some protective method had to be devised

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to prevent the electrode from striking and damaging the mechanism during electrode installation or removal.

Mechanism Description

The resulting mechanism mounted inside a short straight section is shown in Fig. 1. The drive units, Fig. 2, are mounted on the top cover above the mechanism and provide necessary operation through five vacuum sealed penetrations in the cover.

To protect the mechanism from electrode damage, a guard rail was constructed and fastened to the lower face of each section. The insulated rail limits electrode lateral movement during installation or removal.

The three independent movements provided with the mechanisms are as follows: 1) a vertical slow drive, 2) a radial slow drive, and 3) a vertical fast drive. Each motion with its accompanying components will be discussed individually.

Vertical Slow Drive

Vertical adjustment of the detector plate is obtained by a motor driven lead screw drive. The lead screw, supported by bearings on the upstream wall of the short straight section, engages a threaded member on the plate support frame to provide a 12-inch maximum plate movement. The plate can be stored either above or below the beam aperture. The drive motor is mounted on the cover above the lead screw and actuates the screw through a rotary seal. A synchro geared to the motor shaft transmits screw rotation information to a control panel receiver which, in turn, operates a counter to directly indicate plate position with respect to vertical beam centerline.

The target plate is a composite of 1/4-inch thick brass and 1/8-inch thick lead. Space limitations prevented the use of a brass plate with sufficient beam stopping thickness and necessitated the higher density lead attachment.

Radial Slow Drive

Radial positioning of the vertical fast stroke targets is provided by movement of the lead screw-driven transverse carriage shown in Fig. 3. Three guide bars mounted to the plate rigidly support and guide the carriage to insure accurate target positioning. The detector plate is insulated from the guide bars by a 0.003-inch surface of aluminum oxide plasma deposited on the plate in all areas of contact with the bars. The lead screw is rotated, through a bevel gear set, by a flexible shaft. The horizontal drive motor mounted on the cover actuates the flexible shaft through a rotary seal in the cover. A synchro geared to the motor shaft monitors screw rotation to indicate at the control panel radial position of the vertical targets.

Vertical Fast Drive

The two vertical targets which require fast insertion and removal from the beam path and their actuating mechanism are contained by the carriage plate, Fig. 3. The upper target is a 1/2-inch square aluminum member coupled to the target guide through an intermediate fiber glass insulator. The lower target consists of seven 1/4-inch wide by 1/2-inch thick aluminum segments fastened to an aluminum support strip extending below the target guide. Each segment is potentially insulated from the support strip and neighboring segments. A printed circuit board on the support strip connects each segment with individual conductors from a resistor network terminal strip on the opposite side of the carriage. Coaxial cables connect the terminal strip to a vacuum tight feedthrough in the cover. The segmented target is wrapped with insulating tape and aluminum foil to eliminate noise to the amplifiers.

Target motion is obtained through a two-bar linkage by a push-pull ball bearing control cable. A 4-inch push rod stroke produces a 5-inch target motion. The target assembly is confined to vertical motion by a track machined in the carriage plate. The control cable is actuated through a linear seal by a double-rod-ended, double-acting pneumatic cylinder mounted on the cover. A solenoid valve, sequenced by a pulse from the ZGS, controls the cylinder stroking cycle.

To achieve a variable target stroke, a second pneumatic cylinder is coupled to the upper piston rod of the drive cylinder, Fig. 4. The upper cushion cylinder is fastened to a movable platform which is supported and actuated by two vertical lead screws. By means of the platform, the cushion cylinder can be vertically positioned in an 8-inch interval to select the drive cylinder piston stroke necessary to produce the target stroke required. The internal cushions of the upper cylinder provide shock-free deceleration of the drive cylinder piston rod and subsequently the vertical targets. A precision rack attached to the side of the cushion cylinder drives a synchro transmitter through an intermediate gear train. A corresponding receiver at the control panel actuates a mechanical counter to indicate cylinder position within 0.001 inch. An optical survey taken inside the short straight section relates target position with respect to beam centerline to the cylinder position counter. The data is plotted and a typical graph is shown in Fig. 5. These curves are used in diagnostic experiments to determine beam position and profile.

Electrical

The two electrical systems associated with this device are position control and readout, and signal handling.

Position Control and Readout

Plate Drive. (Slow vertical positioning of detectors 1, 2 and 3.) The plate drive controls consist of a reversing starter, momentary pushbuttons, maintained contact lever switch, and upper and lower limit switches (connected as shown schematically in Fig. 6). The limit switches are placed inside the vacuum chamber for the most positive type of protection. A dynamic braking circuit is used to limit coasting of the drive motor.

The position readout comes from both a primary and secondary type. Both are completely outside the vacuum system. The primary readout is a synchro system. It has a transmitter driven off one of the output shafts of a speed reducer whose input is geared to the drive motor. The receiver, located in the Main Control Room (MCR), drives a dual-register counter that reads position, with a resolution of hundredths of an inch, above or below beam centerline. A shutter on the counter automatically closes on one register and opens on the other when the plate is passing through the horizontal beam centerline.

The secondary or backup readout is a 10-turn potentiometer with a 10V power supply and a 10V full scale voltmeter connected to the slider and one end of the potentiometer. The potentiometer is driven off a second output shaft of the same speed reducer that drives the synchro. When the plate is at horizontal beam centerline, the potentiometer is set at its midpoint which is 5V on the voltmeter.

Pilot lights indicate when the upper and lower limits have been reached.

Target Drive. (Slow radial positioning of detectors 2 and 3.) The target drive controls are identical to the plate drive controls. The readout devices are also the same except that they are referenced to the vertical beam centerline.

Fast Drive. (Vertical stroking of detectors 2 and 3.) Both detectors, being joined together mechanically, are actuated by the same drive which is an air cylinder. A 4-way double solenoid-operated air valve is used for actuating the cylinder piston. The sequence of events for this control is as follows. A trigger pulse, originating in the ZGS programmer, arrives at the fast drive chassis to initiate a timing cycle. The timing cycle (adjustable from 200 to 1100 ms) begins with the energizing of a relay and ends with deenergizing. The normally closed and open contacts of the relay energize the proper solenoid on the air valve to give the desired direction of piston movement. Thus the timing cycle includes the piston's initial travel time and its dwell time in the extended position. The piston's return travel time is outside the timing cycle.

A 3-position selector switch determines the initial position of detectors 2 and 3 for automatic use and also a position for manual operation of the fast drive by use of pushbuttons.

The position readout on this drive is a linear potentiometer that has its movable member attached to the drive cylinder shaft. Due to the mechanical arrangement for converting 4 inches of cylinder piston travel to 5 inches of target travel, there is a nonlinear relationship which requires the use of a calibration curve to relate one position with the other. There are also pilot lights actuated by limit switches at both extremities of cylinder travel.

Stroke Length Adjustment. (Detectors 2 and 3.) The drive controls are also identical to the plate drive. In addition, there is a 3-way single-solenoid valve that equalizes the air pressure on both ends of the drive cylinder any time the stroke length is adjusted. This prevents the motor from driving against cylinder pressure.

The position readout is also identical to the synchro system used on the plate drive. However, in this instance, there is a nonlinear relationship between the number on the counter and the length of stroke. Hence, the Fig. 5 curve must be consulted to provide this information.

Pilot lights actuated by limit switches indicate the extremities of adjustment.

Signal Handling

Detector 3 has seven insulated segments, each of which is connected to resistor networks that provide a voltage proportional to the total beam current to the segments and a voltage proportional to a weighted function of the current in each segment. These voltages are used to derive the vertical position of the beam.

The resistor networks on the probe provide three signals. One is called the "sum" which is proportional to the total current to the segments. Another is called the "+" signal which is proportional to the weighted sum of the current to the upper three segments. The last one is called the "-" signal which is proportional to the weighted sum of the current to the bottom three segments. Figure 7 shows how these signals are unloaded from the probe and sent from the Ring Building to the MCR. The sum signal is connected to an operational amplifier which sums a proportional current to each segment. The amplifier sends this sum voltage via coax cable to the MCR. The + and - signals are also connected to summing amplifiers which add the weighted signals from the corresponding three segments. The difference amplifier has an adjustable gain from 1 to 18, and an input common mode rejection ratio at 1 Mc of 55 dB. There is a set of amplifiers with power supply for each of the eight straight sections.

Figure 8 shows the unloading amplifiers in the MCR. The cable-unloading amplifiers detect the difference between the inner conductor and the shield of the cables using 1 kΩ ground isolation and fixed gains of 2. The input common mode rejection ratio at 1 Mc for these amplifiers is 41 dB. The output amplifiers have variable gains which give overall gains at the receiver of 1 to 5 for the difference signal and 2 to 20 for the sum. The delay in the difference signal chain is required by the signal measuring equipment. Fairchild wideband 702A integrated circuit dc amplifiers were used throughout the system.

Detectors 1 and 2 use straight amplification of beam current to them for detection techniques.

Acknowledgments

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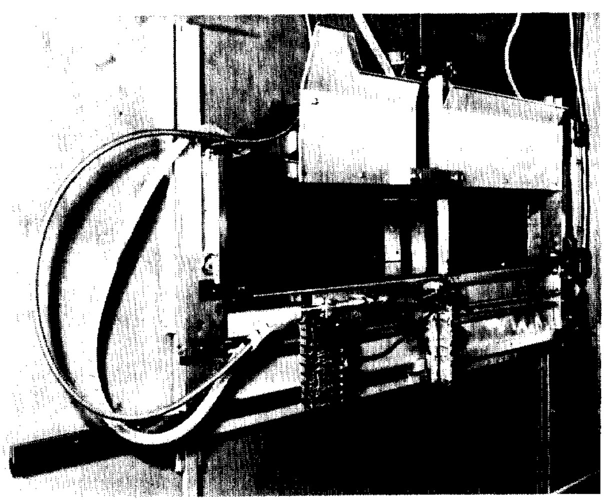

Figure 1. Detector Mechanism Assembly

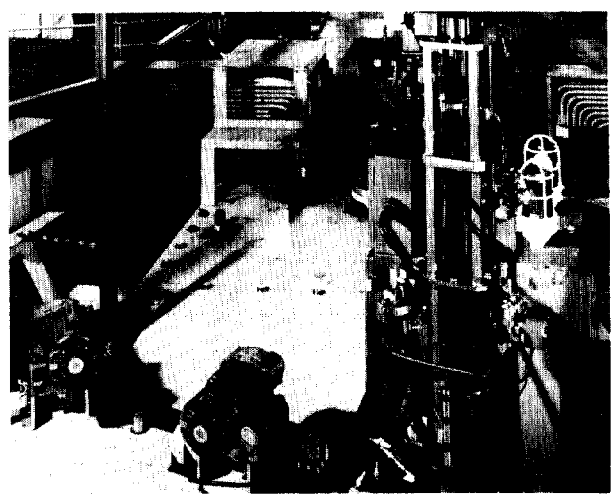

Figure 2. Detector Mechanism Drive Units

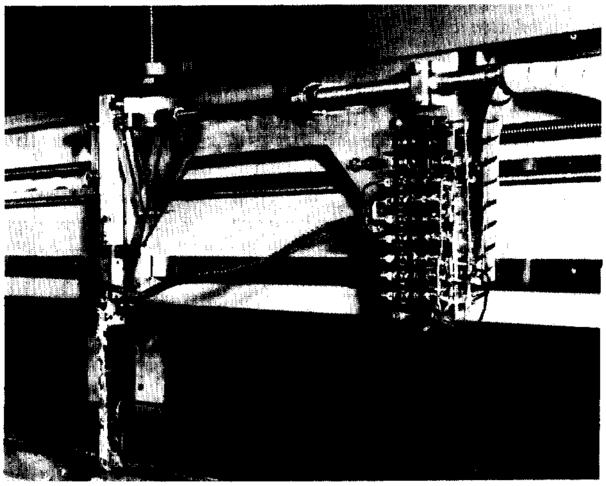

Figure 3. Transverse Carriage and Vertical Target Assembly

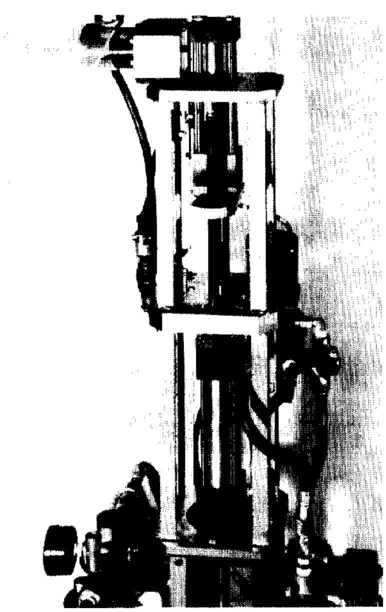

Figure 4. Fast Drive Assembly

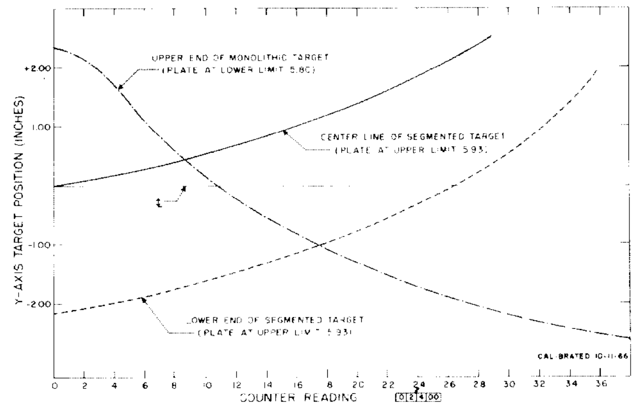

Figure 5. Calibration Curve of Vertical Target Position

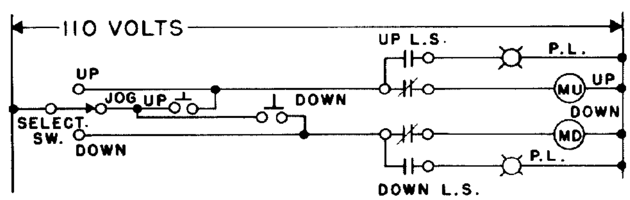

Figure 6. Control Schematic For Plate Drive

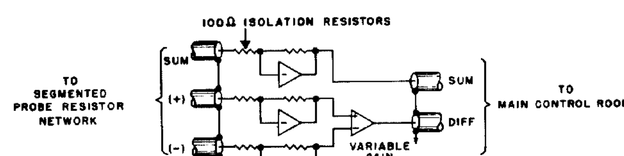

Figure 7. Probe Unloading Circuit in Ring Building

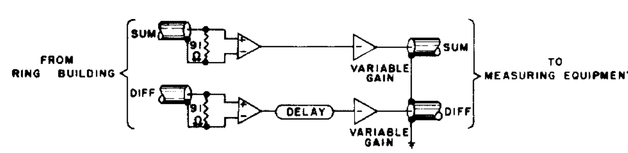

Figure 8. Unloading Amplifiers in MCR