THE NRL CYCLOTRON BEAM CONTROL AND HANDLING SYSTEM

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Summary

The beam handling apparatus and its associated remote control arrangements are described for the NRL Cyclotron Beam Transport System. The need for reducing duplication of controls and power supplies for such a multi-beam-path facility resulted in the development of a rapid master selector system which can be programmed to accommodate the different beam path requirements. All ion optics and beam sensing components along any particular beam path can be activated from a single selector panel, and then individually controlled. The beam transport display, vacuum control display, and control console, are laid out in graphic form wherever feasible in an effort to present readout and control information concisely and continuously. Precision, versatility, modular construction, and ease of maintenance guided the mechanical and electrical design criteria. Design details and prototypes of beam stops, scanners, viewers, collimators, probes, and pumping stations, are discussed.

Introduction

Much of the design of the beam transport system of the NRL cyclotron facility has been guided by the experience of several accelerator groups. We have obtained a considerable amount of detailed information through the cooperation of the Oak Ridge Isochronous Cyclotron (ORIC) and Berkeley 88" groups. Although various accelerator laboratories arrive at quite similar transport systems, the execution of initial design and installation is compromised in many cases by being carried out during the overriding demands of experimental programs. The Naval Research Laboratory has minimized this problem by coordinated planning of the beam transport system with both the cyclotron design and the experimental requirements of the facility. Such a program is greatly expedited by scheduling the fabrication, installation, and testing of the cyclotron simultaneously with that of the beam transport system. The basic criterion of the NRL beam handling and control system is that it be capable of readily transporting an intense high quality beam of ions with precision to any one of eleven experimental stations. These requirements have been largely facilitated by the extensive use of modular equipment design and component standardization.

Remote Control System

At full operation the multiplicity of ion optics and handling apparatus along the eleven beam paths requires some type of switching and selecting control system in order to reduce duplications in the number of power supplies, monitoring systems, and remote controls. Figure 1 shows a block diagram of the 24 volt control and display system. The beam path selector enables one to activate all components along any one of the beam paths by energizing the proper relays in the logic circuits. Following path selection, any individual piece of apparatus along the desired path can then be controlled from the beam optics and handling section of the console. Hence, the number of controls and monitors at the console need only be sufficient to supply the maximum capacity expected for any one beam line.

All switching logic, automatic sequencing, and safety interlocking will be done at the relay racks located in the machinery room. All interconnecting control and signal wiring will go through the main terminal racks located in the counting room. These terminals permit central access to all control circuits and will function primarily as a program patch panel.

The operating condition of the cyclotron, the transport system and the vacuum pumping stations are graphically represented on three separate displays. All display delineations are made up of 1" x 3/4" modular indicators and indicator switches with legendable screens and four color illumination for status coding. This type of construction is conveniently adaptable to various modes of operation. Provisions for control room diagnosis of component malfunction and operational faults include an audible fault annunciation requiring operator acknowledgment. Only certain major categories of faults and their room locations will be visually indicated at the annunciator panels. More detailed information will be indicated at diagnostic panels located at the display racks, on the console, and at the site of the apparatus. At the present time there is no plan for exhaustive fault read-out at a central panel since most of the faults require on site attention. In order to prevent an overly abortive system, we have restricted direct interlocking of beam transport apparatus for cyclotron shut-down to those cases requiring protection of personnel.

Beam Transport Instrumentation

Figure 2 shows the main features of the layout and instrumentation along the three beam paths presently scheduled for initial operation. Although the switching magnets are indicated they will not be required for the beam lines shown. A unique feature of the beam transport system is the 80 ton 135° analyzing magnet which can be mechanically rotated to accommodate branching of the main path prior to beam switching. The 9 ft. radius magnet is rigidly mounted on a carriage which rides on a flat track and pivots about a shaft at P. The carriage is hydraulically driven and will reproducibly position itself at the travel limits. Sequencing of the pumping cycles, rotation, and mechanical coupling to the beam pipes can be controlled either manually or automatically by the path selector control.

All beam preparation is carried out within the cyclotron vault before delivery to the experimental ports. The experimental beam ports are shielded by wall radiation shutters quite similar to those of the ORIC facility. The shutters are interlocked with the shielding doors and the beam path selector.

The control wiring, cables, water, air and gas lines run above the beam lines which average 95 ft. in length. Greater trapping efficiency of the condensable vapors along the beam vacuum lines is obtained by having a relatively large cold surface of the liquid nitrogen traps, in the pumping stations, exposed to the vacuum transport volume. Each pumping station is equipped with a 4", 620 liter/sec oil diffusion pump, separate fore and roughing pumps, automatic liquid nitrogen filler, and a complete dual control system for both on-station, and remote monitoring and cycling control. The vacuum stations are highly interlocked for self protection and the main gate valves will close automatically if any one of several improper pressure or flow conditions exist. The valves are protected from the ion beam by being interlocked with carbon beam stops.

The beam stops are designed to function both as remote total current probes and fail safe protection devices for down-beam elements. The stop consists essentially of a 2" thick cylindrical block of AGOT grade carbon mounted in a heat treated MgO ceramic insulator. The beam stop is electro-pneumatically actuated and controlled such that it will close the beam tube in about 0.3 sec. in the event of either operator decision, power or air pressure failure, or interlock release. Beam current can be read from any one of the stops on demand. Should the beam progressively erode the carbon block permitting beam penetration, a metal plate immediately in back of the carbon block will monitor the penetration current and at a pre-set level will annunciate the burn out condition to the operator.

Since excellent beam viewing is quite essential to rapid alignment, considerable attention has been devoted to the optics of the viewer - TV system in an effort to provide high resolution and minimum distortion. The viewer is designed to be highly adaptable to various methods of visually observing ion beams including the use of fused silica and vicor plates, opaque fluorescence screens, and high temperature foils. In the case of transparent plates, provision is made for controlled edge lighting for illuminating etched reticles and graticules. The general level of illumination within the viewer box can also be controlled for T. V. reticle alignment with opaque screens and control of contrast and T. V. image blooming.

These methods of viewing, however, are limited to low power density ion beams. The desirability of rapidly monitoring beam of a few hundred watts/cm^2 has prompted us to design a rotating wire beam scanner which sinusoidally scans the entire 4" diameter of the beam tube with a 0.043" diameter wire. A synchronous motor rotates the wire in a circle of 2" radius at 1800 RPM. Ion current pulses from the wire drive the vertical amplifier of a CRO. The horizontal sweep signal is generated by a small sine wave generator which is also driven by the synchronous motor. Shaft commutators provide appropriate blanking and centering pulses so that the phase and amplitude of the 30 C.P.S. sweep signal can be adjusted to give a horizontal deflection that is synchronized with the scan wire. Two such scanners driven at right angles provide the X and Y coordinates of the beam, and information about the shape and current distribution.

Beam collimation and definition is accomplished by slit collimators with 7/8" thick graphite jaws mounted on 5/8" thick water cooled aluminum plates. Ion current can be read from any of the collimator jaws on demand. The jaws can be remotely positioned and read out on digital voltmeters with a positioning error of ±0.001" over the entire 4" diameter of the beam tube. Mechanical dial gauges attached to the drive shaft permit local determination and calibration of the jaw position to ±0.001". The remote controls of the slit collimators are arranged to allow either separate or simultaneous positioning of the jaws with traverse speeds of 0.001 inch/sec and 0.050 inch/sec. In the simultaneous mode, the slit width and position of the center line are adjustable from single controls.

Design of a system for both remote and on-station precision control of the mechanical alignment of the quadrupole doublets is in progress. As it is now conceived, each quadrupole doublet will have its mounting table adjustable in such a way as to allow rotation about any horizontal and vertical axis perpendicular to the beam axis plus lateral displacement of the lenses. A limited number of remote control modules can be transferred to any one of the table cross-feeds or left in position on critical doublets for remote alignment.

The major difficulty in precision beam apparatus of this type involves thermal expansion, heat dissipation and mechanical damage caused by power densities of 1 to 10 KW/cm^2. In many cases the functional requirements conflict with good heat transfer design. However, the appropriate use of high temperature materials such as high density carbon, graphite, pyrolytic graphite, and ceramics permits radiation transfer of most of the heat to the walls of the vacuum enclosure. The water cooling serves primarily to limit the temperature excursions of precision mechanical and electrical components. Here, of course, proper containment of radioisotopes necessitates a closed loop cooling system using demineralized water.

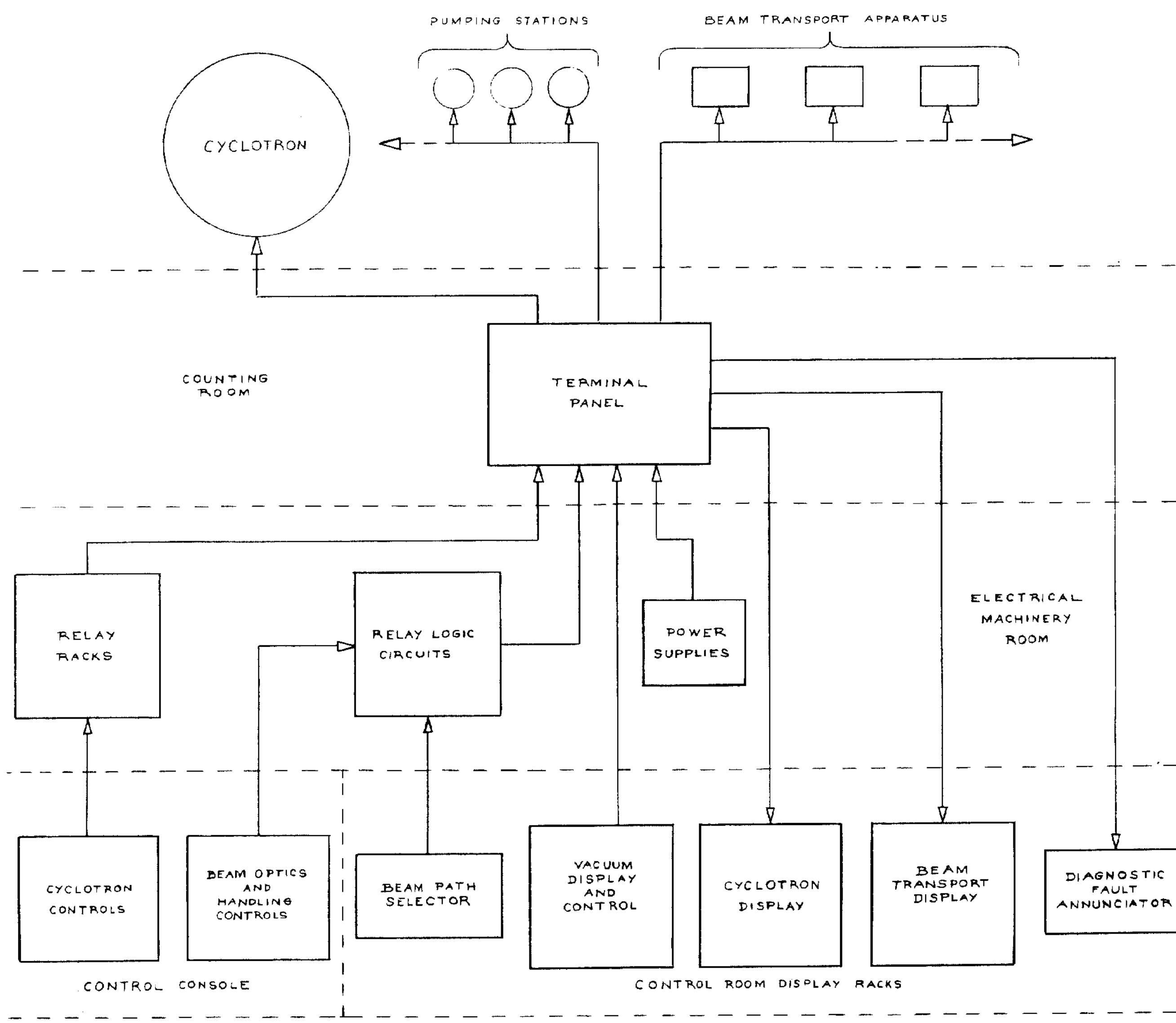

Figure 1. Simplified block diagram showing the NRL cyclotron and beam transport remote control system.

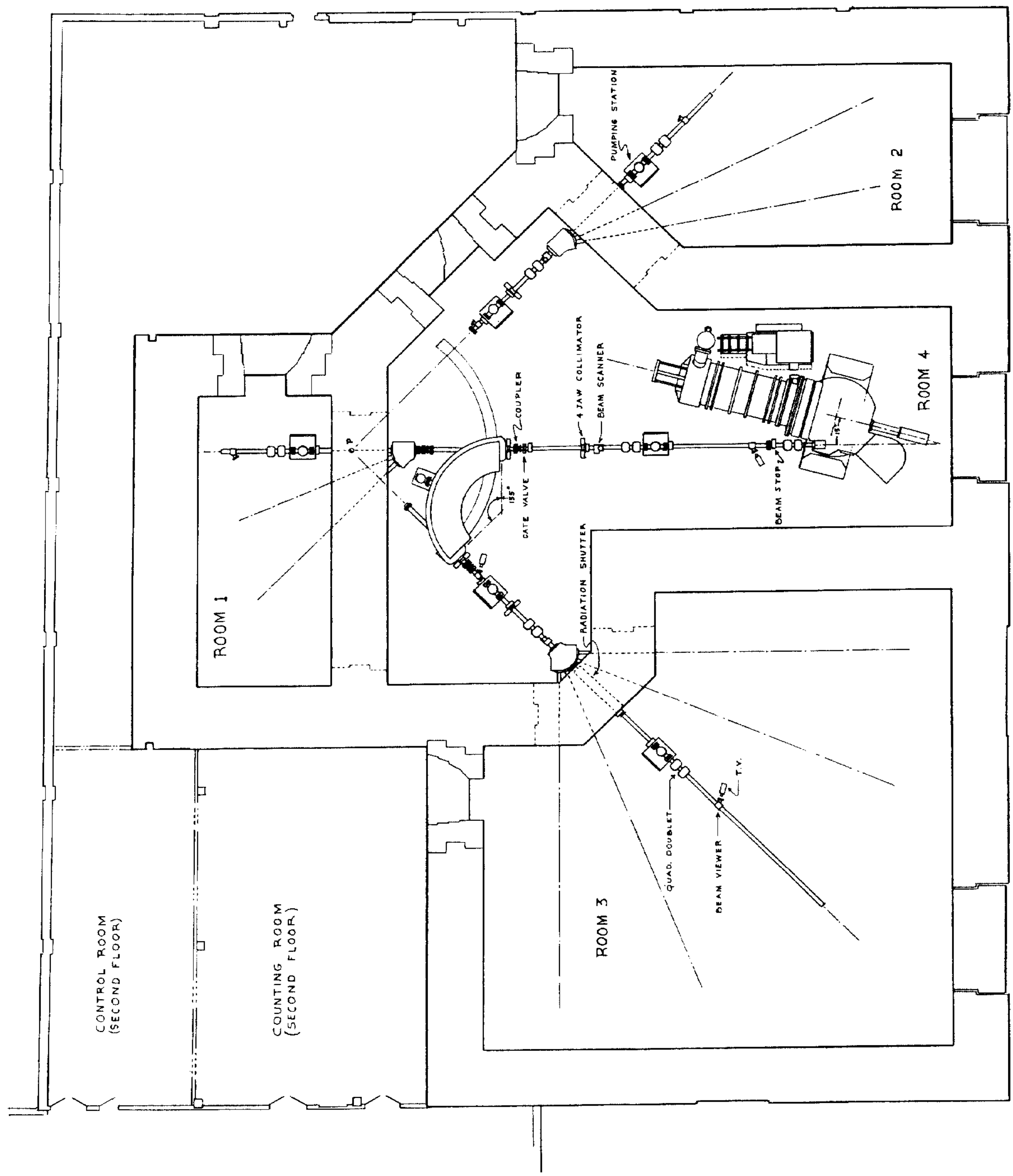

Figure 2. Beam transport system of the Naval Research Laboratory sector focusing cyclotron.