INSTALLATION OF THE CYCLOTRON BASED CLINICAL NEUTRON THERAPY SYSTEM IN SEATTLE

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Summary

A cyclotron facility has been built for cancer treatment with fast neutrons. 50.5 MeV protons from a conventional, positive ion cyclotron are used to bombard a semi-thick Beryllium target located 150 cm from the treatment site. Two treatment rooms are available, one with a fixed horizontal beam and one with an isocentric gantry capable of 360 degree rotation. In addition 33 - 51 MeV protons and 16.5 - 25.5 MeV deuterons are generated for isotope production inside the cyclotron vault. The control computer is also used to record and verify treatment parameters for individual patients and to set up and monitor the actual radiation treatment. Special design requirements had to be fulfilled to allow the installation within a hospital environment.

Introduction

During the past decade fast neutrons have been demonstrated to be the most promising form of immediately available hospital based particle therapy beams. So far most work has been done on accelerators which were originally designed for physics research and which subsequently were adapted for use in cancer therapy. Encouraging results have led to the development of hospital based accelerator systems optimized for therapy purposes. The US National Cancer Institute has awarded contracts to three universities to build and operate neutron therapy facilities. One of these is located at the University Hospital in Seattle.

General Facility Lay-Out

The new facility is located immediately adjacent to the existing Radiation Oncology Department which already operates four linear electron accelerators for X-ray and electron beam treatment. The department is located on the first floor of the University Hospital, ground level being at the third floor. The cyclotron facility is housed in a new underground structure in front of the hospital and can be entered through the Cancer Center in the old building. Therefore up to the central waiting area the patient flow is identical for people being treated with conventional radiation and for neuron therapy patients.

Fig. 1 shows the overall lay-out of the neutron therapy facility. The cyclotron vault is accessible through the maintenance area which will contain a small workshop for minor in-house repairs. Access to the two treatment rooms is through the control area with separate control consoles for the cyclotron/ beamline equipment and for therapy control. All access to the radiation areas is via sliding shielding doors rather than a maze, mainly to save space. For the same reason a single door is used to alternately close one or the other therapy room. All power supplies and the control computer are located on the second floor, above the maintenance area. The cooler room contains a heat exchanger and other refrigeration equipment. Not shown in the diagram is the cooling tower located in another part of the building. Also not shown is the hot lab now under construction an an area adjacent to the cyclotron vault. It will be used to process radioisotopes produced at a target station in the vault.

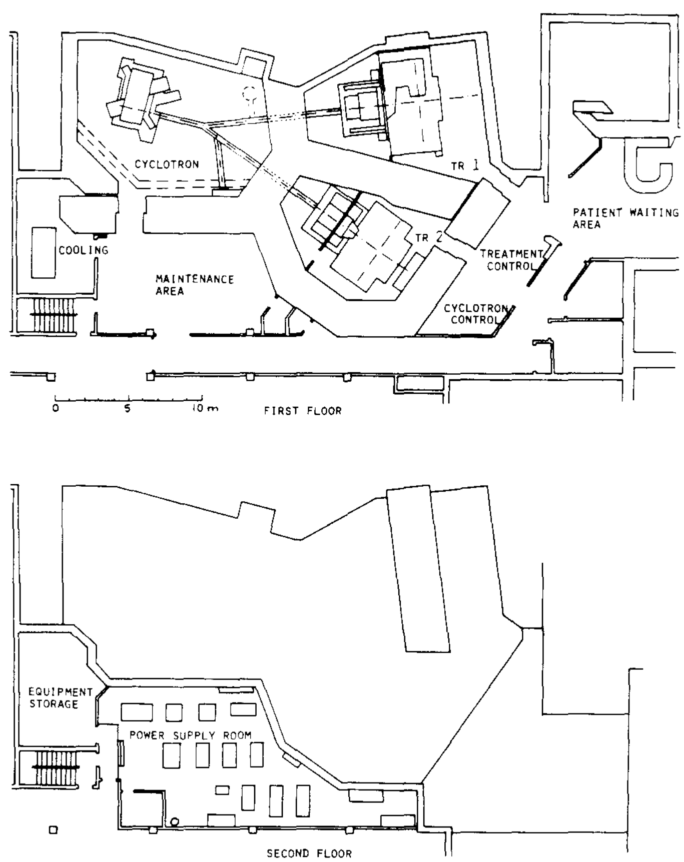

Fig. 1 General Lay-Out of the Facility

Accelerator Equipment

The cyclotron is a commercial MC50 unit built by Scanditronix. It can produce 33 to 51 MeV protons and 16.5 to 25.5 MeV deuterons at 70 μA external current. After the initial trial stage it has been decided to use a 50.5 MeV proton beam for standard therapy operation and the Beryllium targets have been designed accordingly. The variable energy capability and the deuteron option will be used for future experimental work and for isotope production. Scanditronix also delivered the beamline equipment using Danfysik quadrupole triplets, bending magnets and wire-loop beam profile monitors. Beamline height is 1200 mm throughout the facility.

Neutron Therapy Equipment

One of the treatment rooms is equipped with a fixed horizontal beam, the other with an isocentric gantry with 360 degree rotational capability. Both units were built by ELVEN Precision, England, a subcontractor of Scanditronix. The treatment heads are identical on both units. They contain the semi-thick Beryllium target in which the protons lose 50% of the initial energy. The remaining energy is deposited in graphite. Also contained in the head are the beam flattening filters, the dual dosimetry system, a wedge filter system to produce asymmetric dose distributions, the beam defining lamp and an x-ray tube to simulate the neutron field with diagnostic X-rays for patient set-up. The head carries the neutron collimator which can be rotated around the beam axis. In the fixed beam room the collimation is done with interchangeable inserts, a system which is simple but awkward to handle. The isocentric unit is equipped with a variable vane collimator built by Scanditronix. A total of 40 individually powered steel leaves allow for a large variety of field sizes and shapes.

In order to make the 360 degree rotation of the gantry possible, a 3 m-deep pit is necessary to take up the head in its down position. This pit is covered by a moving floor. A system of sliding slats tracks the head automatically as it rotates around, leaving only small gaps.

It is possible to rotate the gantry while the beam is running for so called arc-therapy. An automatic feedback system takes beam current signals from four quadrants at the target location and controls an XY steering magnet in the gantry arm to correct for small mechanical deflections during rotation and keep the beam centered on target.

Control System

All personnel safety interlocks are hard-wired (doors, beam plugs etc). Equipment protection interlocks are hard-wired or handled by a Gould-Modicon 484 controller. All other functions are performed by a PDP 11/23 computer which interfaces with the equipment via the Scanditronix I/O system. The control computer performs the following tasks: power-up/ power-down sequencing, setting and monitoring of magnet currents and other parameters, display of sub-system status, record and verify functions for patient set-up and treatment, therapy system test programs. All patient treatment prescriptions are prepared on the Radiation Oncology VAX 11/780 system and transferred to the PDP 11/23 using DECNET.

Building

The building to house the cyclotron and therapy system had to accommodate the equipment and at the same time meet tight space and budget requirements. Care had to be taken to integrate it architecturally with the demands of a patient care facility. The somewhat peculiar shape of the building reflects these restrictions. Washington state laws for hospital installations required that all wiring over 30 Volt be run in separate conduits. Cable trays could only be used for low voltage signals. This required a very careful coordination between equipment manufacturer and building design team.

All conduits and air ducts penetrating the shielding walls have multiple bends to reduce radiation leakage. Special attention was given to keep neutron activation of the walls and other building parts low to reduce radiation exposure of the radiation technologists. Limestone aggregate was used in all shielding concrete and the amount of metal in walls bombarded by the primary neutron beam was kept to a minimum by using wood furring strips. These wall areas are also covered with borated 4 cm panels to reduce backscattered neutron flux from the wall. Generally the wall thickness is 240 cm, with 270 cm in locations exposed to the primary neutron beam. The same applies for the ceiling. Some walls of the cyclotron vault and the isocentric treatment room could be kept thinner as there is earth fill on the outside.

All radiation areas are air conditioned with negative pressure. No air is recirculated and the exhaust duct is with one exception routed outside occupied areas to join the main building exhaust shaft.

The cyclotron, beamline equipment and some power supplies are cooled with a closed loop deionized water system. The therapy targets have their own closed loop systems to confine higher contamination levels. In the cooler room the heat is transferred to a water/glycol loop which in turn is cooled by a dedicated cooling tower. A small chiller unit ensures that the cooling water for the oil diffusion pumps is below 20 degree C under all conditions.

Equipment Access and Installation

All large equipment components were lowered through an access shaft near the maintenance area and then transferred to the final locations. The access shaft was afterwards converted into a stairwell. If necessary the top can be lifted off again and the stair removed for future accessibility. This solution avoids potential building leakage problems in critical areas like an access plug in the vault ceiling might have created.

Delivery of the treatment room equipment had to be tightly coordinated with construction progress, since finish work in the hallway and control area could only be started after equipment move-in. The headers above the treatment room shielding door consist of removable concrete blocks which were installed only after the gantry main frame was passed through.

Ten-ton crane rails are available in the treatment room ceiling and all heavy lifting during installation could be done using a motorized hoist. The cyclotron vault bridge crane has only a 2 ton capacity and additional rigging equipment was necessary to assemble the cyclotron magnet.

Present Facility Status

The building is at present essentially complete and beam tests are under way. Up to 55 µA proton beam has been run on target (design current is 50 µA, to produce 50 rem/minute at isocenter). Long duration runs have so far been done at only 20 µA. Preliminary measurements showed the adequacy of the shielding walls and doors. It will be possible to run full proton beam current up to a Faraday cup immediately upstream of the closed beam plug and still work safely in the therapy room.

A first set of beam measurements has been completed to establish base parameters necessary for completion of the facility. The feasibility of arc therapy was demonstrated. The dose rate at isocenter was within +-3% during a continuous 360-degree rotation using only the XY steerer in the gantry arm to keep the beam centered on target. This stability was achieved without the planned beam current stabilizer for the ion source. Acceptance tests are planned for this summer and patient treatment is expected to begin later this year.

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Reference

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