PROGRESS REPORT ON THE CONSTRUCTION OF THE NORTHEAST PROTON THERAPY CENTER (NPTC) EQUIPMENT

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Abstract

The IBA proton therapy system selected by the Massachusetts General Hospital (MGH) to equip its new NPTC is presently under construction and test. This paper presents a progress report on the equipment construction. The cyclotron, as well as the rest of the equipment, are being progressively installed in the NPTC building. The acceptance tests of the whole system are foreseen for the end of 1997.

I THE IBA TEAM AND THE NPTC PROJECT

In the early 1994, a team composed by IBA, SHI and GA, with IBA as the prime contractor, was selected by MGH to construct the proton therapy system to equip its new NPTC. The main elements composing this system are:

- a 235 MeV isochronous cyclotron.
- an energy selection system transforming the fixed energy beam extracted from the cyclotron into a variable energy beam (235 to 70 MeV range).
- a beam transport and switching system connecting the exit of the energy selection system to the entrance points of a number treatment rooms.
- two complete isocentric gantries fitted with a nozzle, and a system consisting of two horizontal beam lines, the large field one being equipped with a nozzle.
- a robotic patient positioning system.
- a global control system.
- a global safety management system independent of the global control system. This safety management system uses hardwired interlocks to achieve a safety level meeting applicable standards.

II A CYCLOTRON-BASED SYSTEM

Our goal was to meet all the clinical specifications of a state-of-the-art proton therapy facility in the most simple, reliable and cost effective way. This is the reason for our choice of a fixed energy cyclotron followed by an energy selection system.

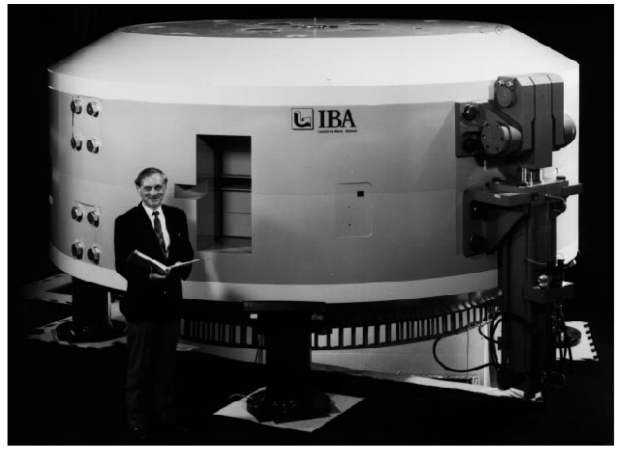

Figure 1: The 235 MeV cyclotron for proton therapy.

With this choice, we have maintained and even increased the advantages of a fixed energy accelerator while completely eliminating the perceived disadvantages. Indeed, compared to the characteristic of a synchrotron which offers the possibility to vary the energy from pulse to pulse, our energy selection system allows for a comfortable 10% energy variation within 2 seconds, with the additional advantage that the high intensity, continuous beam extracted from the cyclotron can be intensity controlled from the ion source within 15 µsec turn on/turn off time. These are essential features for the new treatment modes currently under consideration such as pencil beam scanning for example.

III THE ENERGY SELECTION SYSTEM (ESS)

The energy variability of the system is achieved by means of a carbon wedge used as an energy degrader. As a result of the energy degradation, there is an increase in emittance and energy spread. Emittance slits are therefore used to define the emittance of the transmitted beam, while an analysing magnet system limits the energy spread. Energy changes are completed in two seconds, using laminated magnets and quadrupoles. Figure 2 presents a picture of the energy degrader.

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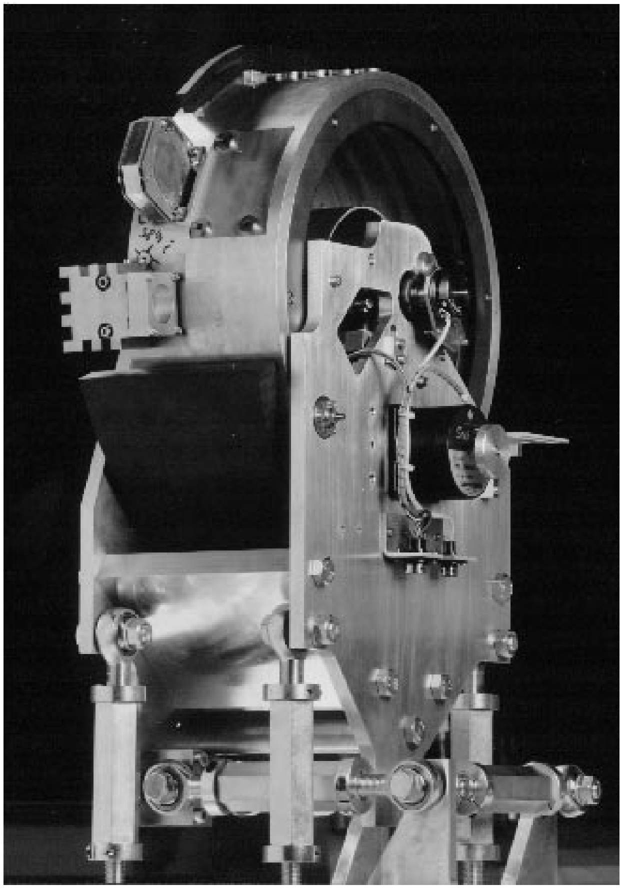

Figure 2: The energy degrader

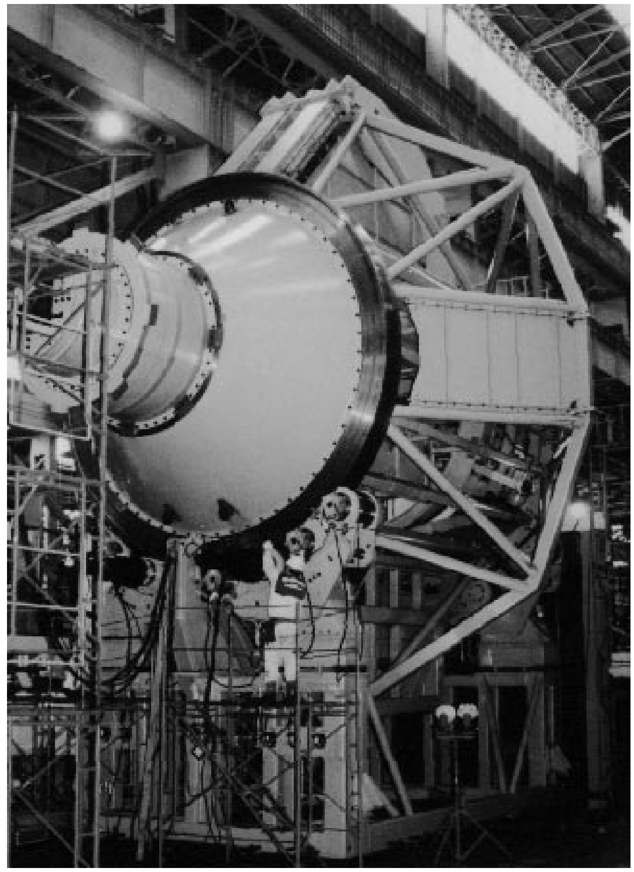

Figure 3: A gantry under construction (the gantry presented here, for illustration, is to be installed at the National Cancer Center in Japan)

IV THE BEAM TRANSPORT SYSTEM

The beam transport and switching system connects the exit of the energy selection system to the entrance points of the gantries and the fixed beam lines. All bends are achromats. At strategic points along the beam transport system, the beam characteristics are monitored by grid ionisation chambers. This information can be used for automatic tuning.

V THE GANTRIES

The gantry is the movable portion of the beam transport emerging from the cyclotron and terminating at the patient. The gantry structure is designed to minimize interference with the beam delivery system, provide maximum access to the patient, and maintain the isocenter position to within a sphere of confusion of radius 1 mm under all operating conditions, including all orientations, of the gantry. It is made up of a basic rotatable structure and a beam transport line which utilises one 45° bending magnet, one 135° bending magnet, nine quadrupole magnets, two sextupole magnets, three trim steering coils, and a nozzle. A simple rotating seal connects the moving portion of the beam transport tube to the stationary portion at the end of a 60° achromatic bend leading to the gantry.

The NPTC equipment includes two complete isocentric gantries. Each gantry is an achromatic system. Its optics can be tuned for either beam scattering/wobbling or for pencil beam scanning. As for the energy selection system and the beam transport system, the use of laminated magnets and quadrupoles allows for energy changes in two seconds.

VI THE NOZZLES

The isocentric gantries and one of the horizontal beam lines, the large field one, will be fitted with nozzles. The functions of the nozzles include the 3-D beam shaping to irradiate the target volume at a constant dose, the beam monitoring and dosimetry, the help for patient positioning and field alignment verification, and the support of patient specific devices. The spreading techniques provided by the IBA nozzle are the double scattering for small to moderate fields, and the wobbling technique for the largest and deepest fields. The nozzle is compatible with a future upgrade to pencil beam scanning.

VII THE PATIENT POSITIONING SYSTEM

The accuracy of proton therapy is such that patient positioners should be submillimeter precision instruments. Our Proton Therapy Equipment therefore includes a patient positioner specifically designed for proton therapy. It positions the patient to permit the beam to be delivered with great accuracy to any point in the patient from any angle. Coupled with the gantry which provides 360° rotation of the beam about one vertical axis, the patient positioner must provide a minimum of four axis of motion (three translations and one rotation) to accomplish this objective. In fact, the patient positioner for the NPTC has six degrees of freedom - four axes as defined here above, and couch pitch and roll to accomplish fine scale adjustments.

VIII THE CONTROL SYSTEM

The NPTC Control System is developed on three levels: the equipment control level where we have the process controllers close to the equipment, the management level, which is responsible for the operation of a set of high level functions, and the user interface level with the operator interface. Networks provide the connection between the different levels and between units at the same level. The process controllers, using VME card cages or industrial PLCs, are connected through a highly reliable serial bus (CANBus). An Ethernet network allows the connectivity from the equipment control level to the user interface level and the database system running on UNIX-based work stations.

IX STATUS OF THE NPTC PROJECT

The construction of most of the subsystems is reaching completion. The cyclotron and the ESS were shipped to Boston at the end of March 1997, after successful completion of all cyclotron and ESS factory tests in IBA's assembly hall, including Bragg peak measurements. As far as the cyclotron is concerned, beam was accelerated up to the maximum energy, with extracted beam intensities up to 1 μA. This equipment arrived at the NPTC mid-April and is presently being installed.

The beam transport system will be completely mounted and ready to accept beam (on site) in September 1997.

The assembly of the gantry structure mechanical parts was done in March (vertical position). Shipment of the first gantry will take place at the end of April, after factory tests with the magnets installed. The second gantry will follow one month behind.

Some parts of the nozzle are still under final design (snout, bolus), while the other parts are under fabrication. Beam tests of the nozzles are scheduled in August and September 1997.

The patient positioning system assembly started at GA in early 1997 and the factory tests are underway.

Finally, work on the control system and on the safety system is progressing well. The computer network is installed and was connected to the available equipment in the assembly hall at IBA (before shipment). A group of seven computer scientists and engineers is developing and testing the software.

The whole system acceptance tests on site are expected to be performed at the end of 1997, and the first patient should be treated by the end of 1998.

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