MCC-30/15 CYCLOTRON-BASED SYSTEM FOR PRODUCTION OF RADIONUCLIDES PROJECT

A.P. Strokach, Yu.N. Gavrish, S.V. Grigorenko, V.I. Grigoriev, M.L. Klopenkov, R.M. Klopenkov, V.G. Mudrolyubov, G.V. Muraviov, V.I. Nikishkin, V.I. Ponomarenko, JSC "NIIEFA", St. Petersburg, Russia

Abstract

The projected MCC-30/15 cyclotron system is intended for operation in high-technology nuclear medicine centers. The system consists of a cyclotron, target systems for production of radionuclides in liquid, gaseous and solid states and a system for transport of accelerated ions to final units. The updated MCC-30/15 cyclotron with new systems for external injection, RF power supply and acceleration will ensure production of accelerated proton and deuteron beams in energy ranges of 18-30 and 9-15 MeV and currents not lower than 200 and 70 µA, respectively. Target systems are equipped with mechanisms for remote replacement of gaseous and liquid targets. Modular configuration of the beam transport system will allow the production of isotopes and carrying out of researches to be performed in separate experimental halls.

INTRODUCTION

The strategy for the development of nuclear medicine in RF is aimed at solving import substitution problems and providing international competitiveness of the equipment, which is one of the most high-technology products of industry. One of the main purposes of nuclear medicine is early diagnostics of diseases, which can significantly increase the efficiency of treatment and reduce the time needed. The most important tool for early diagnostics is functional diagnostics based on application of modern radiopharmaceuticals and apparatus for visualization of radionuclides' distribution in a patient' s body. Diagnostic studies in cardiology, oncology, neurology, etc. need a wide assortment of radiopharmaceuticals, for which purpose radioisotopes of high purity and a possibility for their production in close vicinity to a consumer must be provided. It is evident that organization of studies aimed at the development and application of new radiopharmaceuticals is possible only in research centers equipped with cyclotron equipment generating accelerated beams of hydrogen ions in a wide energy spectrum, which is proved by the world practice. The most expedient seems the use of a cyclotron with the energy of protons ranging from 18 to 30 MeV and that of deuterons varying from 9 to 15 MeV.

THE MAIN OBJECTIVES OF THE PROJECT

Prototype of the MCC-30/15 cyclotron has been designed and manufactured in the Efremov Institute (JSC "NIIEFA"). Put into operation in 2010 (see Fig. 1) [1-2].

Figure 1: General view of the MCC-30/15 cyclotron.

The experience gained in the process of the cyclotron operation has demonstrated the correctness of engineering solutions made at stages of its designing, development and manufacturing. However, more stringent current requirements for such facilities brought into being an urgent need for updating the cyclotron equipment while keeping unchanged its basic concept, namely, vertically located median plane, shielding-type magnet (which requires a radiation-shielded hall of a minimum size and offers easy maintenance/repair), combined functions of the magnet yoke and vacuum chamber, acceleration of H^- and D^- ions at one operating frequency (the 2[nd] and 4[th] harmonics).

The main purpose of the updating is attaining of higher intensity of accelerated ion beams and reliability of the system under long-term operation modes as well as designing of a new project of a system for beam transport to six remote targets. The main parameters and characteristics, which are supposed to be attained as a result of the updating are shown in Table 1.

Table 1: The main parameters of the cyclotron with updated systems.

Parameters	Values
Type of ions • Accelerated • Extracted	 H^-/D^- H^+/D^+
Energy of accelerated ions, variable, MeV • Protons • Deuterons	 18-30 9-15
Number of devices for simultaneous beams extraction.	2
Total current of extracted beam, not less than, µA • Protons • Deuterons	 200 70
Power consumption, no more than, kW • Stand-by mode • Operating mode	 30 120

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The main tasks to be solved in the course of updating:

- ***External injection system***.Development of a new source of hydrogen ions based on a cold cathode, which will allow an increase in the time of its continuous operation (with a heated cathode it is not more than 500 hours).
- Attaining of higher injection energy up to 24-26 keV, which will improve conditions of the beam forming in the injection line and increase the ion beam capture in the acceleration process.
- ***Resonance accelerating system.*** Development of new dee and dee stems constructions with an enhanced mechanical strength and thermal stability.
- Development of a new construction of the central cyclotron region providing higher capture of the ion beam in the acceleration process and offering enhanced mechanical strength.
- Development of a new construction of the AFT trimmer with the frequency tuning maximally close to linear.
- Development of an additional system for water cooling of the resonance accelerating system meeting more stringent requirements for thermal stabilization compared to the water cooling of the whole cyclotron system (water temperature stabilization at the resonance system output is in the range of±1ºC).
- ***Main electromagnet.*** Modification of shims' construction to simplify the correction of the magnetic field topology when changing the type of ions to be accelerated.
- Modification of the vacuum chamber casing and central region of pole pieces with allowance for the new construction of the resonance system.
- ***The RF power supply system***. Designing of a new specialized RF generator adapted for the cyclotron equipment. This necessity results from a negative experience gained in installation and operation of the purchased equipment including foreign firms.
- Using of a home-made 4 kW transistor amplifier as the 1st stage of the power amplifier seems reasonable.
- Designing of a module for control and stabilization of the signal amplitude on the basis of positive experience gained at designing and installation of similar equipment of the C-80 cyclotron system.
- ***Vacuum system***. Keeping in mind requirements for import substitution, we made a decision to stop using of foreign high-vacuum pumps and apply diffusion and cryopumps of home manufacture.
- Pressure sensors with an extended service life will be used in measurements (possibility for long-term failure-free operation under intensive neutron fields and γ-radiation).
- ***Hookup elements***. When designing hookup elements (probes, stripping devices, trimmer), vacuum linear translators are provided for to ensure a high positioning accuracy and reliability under long-term operation.
- ***The beam transport system*** is built by the modular principle using standard electromagnets, quadrupole lenses, diagnostic devices designed in the Efremov Institute. Any beam transport to remote targets meeting the requirements of the End User can be provided.
- ***Target systems.*** Development of a mechanism for remote replacement of liquid and gaseous targets (up to five targets of different yields and applications), (see Fig. 2).
- Designing of a liquid target for production of ^{18}F isotope with a yield of not less than 8 Cifor 2-hour irradiation. Possibility for work at an accelerated proton beam current up to 100 μA.
- Designing of a special system for irradiation of solid targets (production of ^{64}Ci, ^{67}Ga, ^{111}In, ^{124}I isotopes, etc.), which allows an irradiated target to be automatically discharged to a shielded box or to a system delivering an irradiated material to this box.

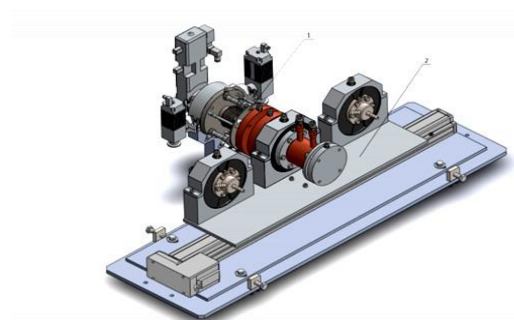

Figure 2: System for remote replacement of liquid and gaseous targets (three in total).

Systems of power supply, water cooling and automatic control will undergo no fundamental updating. Their final configuration is defined at the stage of approval of the beam transport system and target systems' composition by the End User. The cyclotron system to be updated meets to the utmost the needs of university centers planning a wide spectrum of researches in the fields of nuclear medicine, neutron and radiation physics, beam neutron therapy, diagnostic and therapeutic practice applying nuclear medicine methods as well as training of specialists in all the aforementioned fields.

An example of such a research center is a center created by cooperative efforts of specialists from the Efremov Institute, Russia and the Jyvaskula University, Finland. The equipment of the MCC-30⁄15 cyclotron system was designed in parallel with the elaboration of construction documents; manufacturing of the equipment and construction works were finished simultaneously. The whole cycle of works has been performed within 2 years, (see Figs. 3 and 4).

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Figures 3, 4: Works on creation of a research center on the site of the University in Jyvaskula, Finland.

CONCLUSION

Guided by far-reaching plans of a number of Universities, both in Russia and abroad, to date we have designed several possible layouts of cyclotron centers equipped with a cyclotron with a maximum energy of 30 MeV. The main lines of activities of similar centers will be the following:

- Development and testing of new radiopharmaceuticals on the basis of promising isotopes for PETand SPECT diagnostics.
- Carrying out of a wide range of applied researches on the practical use of neutron therapy methods for the treatment of especially dangerous oncologic diseases.
- Preparation of radiopharmaceuticals obtained on the basis of radioisotopes produced by cyclotron for routine diagnostics by nuclear medicine methods.
- Production of radioisotopes, synthesis of radiopharmaceuticals on their basis and commercialization, which will provide income and profitability of a center.
- Studies, including those on a commercial basis, on the effect of radiation on radio - electronic components and units.
- Research studies in the radiation material science using high-energy flows of hydrogen ions, neutrons and γ-radiation.

Such centers will prove rather important in training and re-training of specialists for nuclear medicine, applied physics, etc. One of possible layout of the cyclotron system is shown in Fig. 5.

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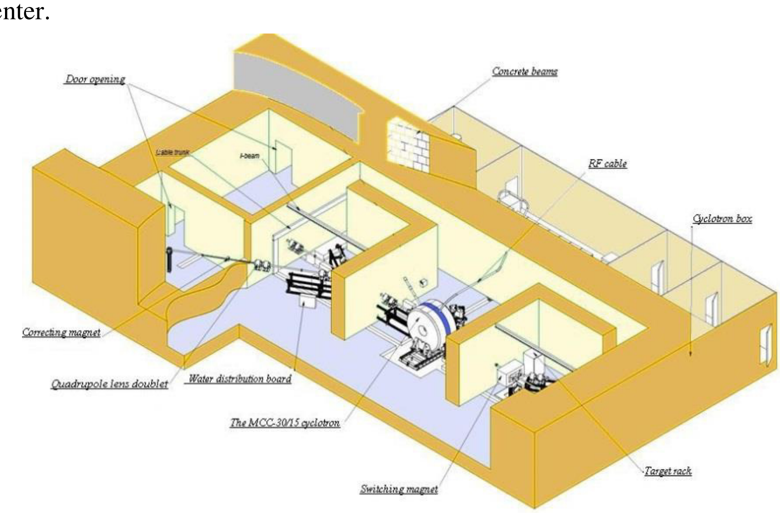

Figure 5: One of possible layouts of the cyclotron system.

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