CC-18⁄9M CYCLOTRON SYSTEM

A.P. Strokach, O.L. Veresov, Yu.N. Gavrish,A.V. Galchuck, S.V. Grigorenko, V.I. Grigoriev,
M.A. Emeljanov, M.L. Klopenkov, A.N. Kuzhlev, V.G. Mudroliubov, G.V. Muraviov,
V.I. Nikishkin, V.I. Ponomarenko, Yu.I. Stogov, S.S. Tsygankov,
JSC "D.V. Efremov Institute of Electrophysical Apparatus", St. Petersburg, Russia

Abstract

The CC-18/9M cyclotron system has been designed, manufactured and delivered to NIITFA, Moscow. The system consists of an updated CC-18⁄9M cyclotron and a targets system. The cyclotron is intended to produce accelerated proton and deuteron beams with an energy of 12-18/6-9 MeV and current up to 150/70 μA, respectively. For this purpose, a shielding-type electromagnet and a resonance system have been afresh designed. The target system for the production of F-18 and C-11 radionuclides for PET has been designed in NIIEFA for the first time.

The CC-18⁄9M cyclotron system was designed for the delivery to JSC «NIITFA», Moscow with a view to creating a pilot PET center. The cyclotron system consists of an updated CC-18⁄9M cyclotron and a target system. This cyclotron is a new version of three CC-18⁄9 machines manufactured previously and delivered to PET centers of the University in Turku, Finland, Russian Research Center for Radiology and Surgical Technologies, Pesochny, St. Petersburg and «VNIITF », Snezhinsk town, Chelyabinsk region, Russia. To widen the possibilities of application and increase the marketability of the CC-18⁄9M cyclotron, the energy of accelerated proton and deuteron beams is made variable in the range of 12-18 and 6–9 MeV, respectively. Simultaneously, the design current of protons and deuterons is increased by one and a half in comparison with the original model, i.e. up to 150 и 70 μA, respectively.

The new version of the cyclotron keeps the continuity in the main engineering solutions proven in CC-18⁄9 and MCC-30⁄15 machines [1, 2]:

- shielding-type electromagnet with a limited number of holes in the shielding,
- vertical median plane to give an easy access to in-chamber devices by moving apart the movable part of the magnet along the guides,
- the vacuum chamber of the cyclotron made as a part of the electromagnet,
- the resonance system located completely inside the vacuum chamber of the electromagnet [3],
- extraction of beams of accelerated protons and deuterons by stripping negative ions on carbon foils practically with no loss of intensity,
- an external injection system, which significantly reduces the working gas admittance from the source to the vacuum chamber, facilitates production of high vacuum and consequently reduces the losses of ions in the acceleration process by molecules of the residual gas [4],
- acceleration of negative ions of hydrogen and deuterium at one fixed frequency of the RF field (the 2nd and 4th harmonics, respectively),
- installation of movable shims in special recesses to correct the magnetic field topology and to ensure isochronous field when changing the type of ions to be accelerated,
- extraction of proton and deuteron beams through 3 windows made in the vacuum chamber. Two windows are intended for installation of targets directly onto the magnet ("near" targets) and the third window is used to transport the beam to remote targets,
- simultaneous extraction of beams with a max energy to one of remote and one of near targets,
- standard set of components of a beamline transporting the beam to remote targets: matching magnet, 2 correcting magnets, doublet of quadrupole lenses and switching magnet making possible the beam transport to 3 target devices,
- compete automatic control of the cyclotron system.

In the process of designing, the following principal modifications were made, which significantly improved the conditions of service and maintenance/repair compared to the original model:

- A new resonance accelerating system consisting of 2 mirror-symmetrical resonators has been designed. In CC-18⁄9 cyclotrons, one resonator was used, the central conductor of which consisted of two dees, two stems, which had a common part with a shorting flange. The new design allowed the loss power to be reduced from 18 to 13 kW. Due to the resonance system symmetry, was reduced the effect of thermal deformations, which in the original machine limited the beam current in the continuous mode. The operating frequency of the new resonance system of 40.68 MHz (38.2 MHz -in the original model) coincides with the operating frequency used in the MCC-30⁄15 cyclotron., so in both models identical RF power supply systems can be used.
- The new cyclotron design allowed 2 cryogenic pumps to be installed on the vacuum chamber, which provided more uniform distribution of pressure and, as a consequence, lower losses of ions in the acceleration by molecules of the residual gas.

ISBN 978-3-95450-170-0

- The main magnet of the cyclotron was designed anew taking into account modifications in the resonance and vacuum pumping systems. Manufacturing of the whole magnet yoke at one enterprise, the Novokramatorsky machine-building plant, starting from steel making to metal finishing treatment, allowed the beam, pillar and pole of each half-yoke to be made as an integral element. Such a design provides uniform magnetic properties (steel of one melting cycle), makes significantly easier the magnet yoke assembly and increases the accuracy of critical dimensions.
- A new system of shims similar to that used in the MCC-30/15 cyclotron has been designed (4 shims instead of 16 used in the original model), which made much more simpler shims' manufacturing and change of the magnetic field topology when the type of accelerated ions is changed. Shims are located in valleys not occupied with resonance system dees [5].
- New constructions of stripping devices, probe and AFT trimmer has been designed. Due to the use of standard articles, linear translators, which ensure their travel in vacuum, less labor efforts and time were spent for manufacturing the aforementioned equipment in the NIIEFA production department.
- It was for the first time in the NIIEFA practice, that a cyclotron was delivered together with a target system. Design and operational documentation for the target system of the cyclotron has been worked out. The target system consists of a target station with systems for fore-vacuum pumping, water and helium cooling; liquid and gas targets; control system and system for target loading[6].

The main characteristics of cyclotron are given in Table1.

Table1: Main characteristics of the cyclotron

System, parameter	Characteristics, value
Accelerated ions	H-/D-
Extractedions	H^+/D^+
Beam energy, variable, MeV	12-18/6-9
Beam current, μA	150/70
Electromagnet	
- type	shielded-type
- pole diameter, cm	1150
- mass, t	34
Resonance system	
- operating frequency, MHz	40.68
- dee number	2
- RF voltage amplitude,kV	38
RF power,kW	20
Ion source	external
Operating mode	continuous/pulse
Total power consumption, not more, kW	
- beam on target	90
- stand-by mode	15

The cyclotron system has been designed, delivered and installed in the laboratory building in JSC «NIITFA», Moscow. Fig.1 demonstrates the layout of the cyclotron system equipment in rooms with radiation shielding. At the forefront, diagnostic units with target devices are shown, under which units for targets' loading with target materials are placed. Fig.2 demonstrates the movable half-yoke of the main electromagnet moved apart and in-chamber units can be seen. The target station rack is given in Fig.3.

Figure 1: Cyclotron system.

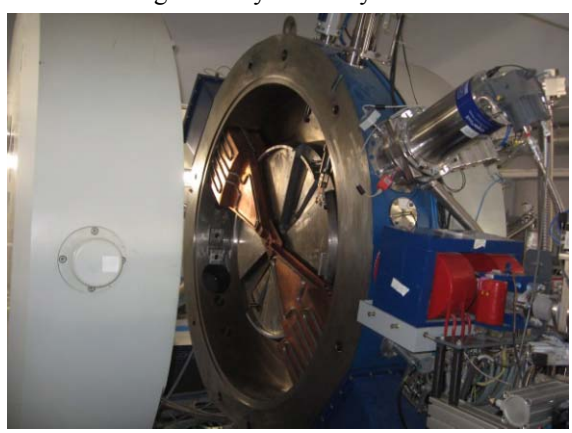

Figure 2: Electromagnet with open vacuum chamber.

Figure 3: Target station rack.

To date, the adjustment works have been finished, and the design ranges of proton energy and extracted beam current have been attained. Final acceptance tests have

ISBN 978-3-95450-170-0

been performed with extraction of proton beams to targets. Tests of the target system with production of F-18 and C-11 and their transport to modules of radiopharmaceuticals' synthesis have been done.

REFERENCES

[1] P.V. Bogdanov, M.F. Vorogushin, V.P. Kukhtin, E.A. Lamzin, A.P. Strokach, S.E. Sychevsky. RF Patent №2373873 H05H «Isochronous Cyclotron for Acceleration of Several Species of Charged Particles». Bulletin № 32, 20.11.2009

[2] P.V. Bogdanov, I.N. Vasilchenko, M.F. Vorogushin, A.V. Galchuck, S.V. Grigorenko, V.G. Mudrolyubov, A.P. Strokach, S.E. Sychevsky, "New Compact Cyclotrons for Radionuclides Production, Proceed. of RuPAC'08.

[3] P.V. Bogdanov, V.G. Mudrolyubov, S.A. Silaev, "Specific Features of Accelerating Systems of CC-18/9, CC-12 and MCC-30/15 Compact Cyclotrons', Voprosy Atomnoi Nauki i Tekhniki, series «Electrofizicheskaya Apparatura», №.5, St. Petersburg, 2010, pp. 65-74.

[4] P.V. Bogdanov, I.N. Vasilchenko, O.L. Veresov, S.V. Grigorenko, Yu.V. Zuev, M.T. Козиенко, V.G. Mudrolyubov, A.P. Strokach, S.S. Tsygankov, "Systems for External Injection of Negative Ions for Compact Cyclotrons", Voprosy Atomnoi Nauki i Tekhniki, series «Electrofizicheskaya Apparatura», №.5, St. Petersburg, 2010, pp. 74-83.

[5] P.V. Bogdanov, A.A. Budtov, I.N. Vasilchenko, M.F. Vorogushin, S.V. Grigorenko, V.G. Mudrolyubov, S.A. Silaev, Yu.I. Stogov, A.P. Strokach, S.E. Sychevsky, N.F. Shilkin, "The MCC-30/15 Medical Compact Cyclotron with Variable energy of Accelerated Ions", Voprosy Atomnoi Nauki i Tekhniki, series «Electrofizicheskaya Apparatura», №.5, St. Petersburg, 2010, pp. 32-48.

[6] E.N. Abramov, Yu.N. Gavrish, P.A. Gnutov, B.N. Zabrodin, M.L. Klopenkov, R.M. Klopenkov, K.A. Kravchuck, A.N. Kuzhlev, A.A. Melnikov, G.V. Muraviov, A.V. Regel, A.P. Strokach, "Target System for the CC-series Cyclotrons Designed and Manufactured in NIIEFA", Problems of Atomic Science and Technology, 2013, V. 6(88), Series "Nuclear Physics Investigation" (61), Pp. 201-204.

ISBN 978-3-95450-170-0