

25 - 70 MEV VARIABLE ENERGY CYCLOTRON FOR RADIO-ISOTOPE PRODUCTION

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Summary

Two 25 - 70 MeV proton variable energy cyclotrons (model 750PV) were constructed and are now under operation. 70 MeV protons are mainly used for the production of high purity I-123 with the nuclear reaction of I-127(p,5n)Xe-123→I-123. 30 MeV protons are also used for the production of Ga-67, In-111, Tl-201 and so on. One of them was supplied to Medi+ Physics, INC. in USA and another to Nihon Medi+ Physics Co., LTD. in Japan.

Main features of model 750PV are as follows.

1. High power beam current extracted is available.
2. Full computer control system is realized for easy operation and quick detection of a fault equipment.
3. Size is compact and power consumption is low.

Introduction

There have been mainly two procedures to produce high purity I-123 that is useful these days in the field of nuclear medicine. One is to bombard a 30 MeV proton beam on such a rare isotope as Xe-124 target material that is tremendously expensive. And another is to bombard a 70 MeV proton beam on a I-127 target material that is easily obtainable. A cyclotron has been the most approved accelerator for these purposes. However, for the latter procedure, there was somewhat difficulty that the 70 MeV cyclotron dedicated to the I-123 production was not available commercially.

To reply to such a market requirement, Sumitomo heavy industries Ltd. and CGR-MeV designed and constructed 25 -70 MeV variable energy cyclotron on a basis of our experience in model 560 that is K=42MeV machine and model 930 that is K=100MeV machine, in collaboration with each other. This machine can also be used as a back-up to produce Ga-67, In-111, Tl-201 and so on, because of a variable energy type. It is needless to say that the production of I-123 from Xe-124 is possible with this cyclotron.

Basic specifications

Performances : Performances of the machine are summarized in table 1.

Table 1 : Performances (proton)

| | | |
|--------------------------------------|-------------|-------------------|
| proton energy range : | 25 - 70 MeV | |
| maximum intensity of internal beam : | 250µA | |
| maximum intensity of extracted beam | energy | maximum intensity |
| | 70 MeV | 65µA |
| | 60 | 75 |
| | 50 | 90 |
| | 40 | 100 |
| | 30 | 100 |
| | 25 | 100 |

Deuteron, helium 3 and alpha particle can be provided if they are required. Beam energy range and maximum intensity are summarized in table 2.

Table 2 : Performances

| | | | |
|---------------------|---------------|----------|-----|
| Energy range : | | | |
| deuteron | 12.5 - 35 MeV | | |
| helium 3 | 20 - 90 | | |
| alpha | 25 - 70 | | |
| Maximum intensity : | Internal | External | |
| deuteron | 250 µA | 100 µA | |
| helium 3 | 100 | 50 | (1) |
| | 50 | 20 | (2) |
| alpha | 100 | 50 | (1) |
| | 50 | 20 | (2) |

- (1) at the high energy range
(2) at the low energy range

Characteristics : Characteristics of the machine are summarized in table 3.

Table 3 : Characteristics

Electromagnet :

| | |
|--|---------|
| number of sectors | 4 |
| weight (metric tons) | 115 |
| pole diameter (m) | 1.8 |
| gap maximum (cm) | 31.5 |
| gap minimum (cm) | 13.3 |
| maximum average magnetic field at the extraction radius (KG) | 16.4 |
| number of ampere turns in the main coils (AT) | 275,200 |
| number of trim coils (pairs) | 10 |
| number of harmonic coils (pairs) | 4 |
| extraction radius (mm) | 750 |

Radiofrequency :

| | |
|--------------------------|---------|
| frequency range (MHZ) | 13 - 26 |
| frequency stability | 10E-6 |
| number of dees | 2 |
| dee span angle | 90° |
| number of cavities | 2 |
| maximum dee voltage (KV) | 45 |
| power tubes (KW) | 2 X 50 |
| beam space (mm) | 35 |

Ion source :

| | |
|-----------------------|--------------------------------|
| type | Livingstone - Jones |
| location | internal vertically introduced |
| maximum arc power (W) | 500 |

Extraction :

| | |
|-------------------------|----------|
| electrostatic deflector | |
| maximum field (KV/cm) | 100 |
| angular span | 55° |
| magnetic channel | active |
| maximum induction (KG) | 3.5 |
| angular span | 18° |
| gradient corrector | one pair |

Vacuum system :

| | |
|--|----------|
| oil diffusion pump (l/s) | 2 X 2000 |
| main primary mechanical pump (cu.m./h) | 40 |
| auxiliary primary pump (cu.m./h) | 20 |

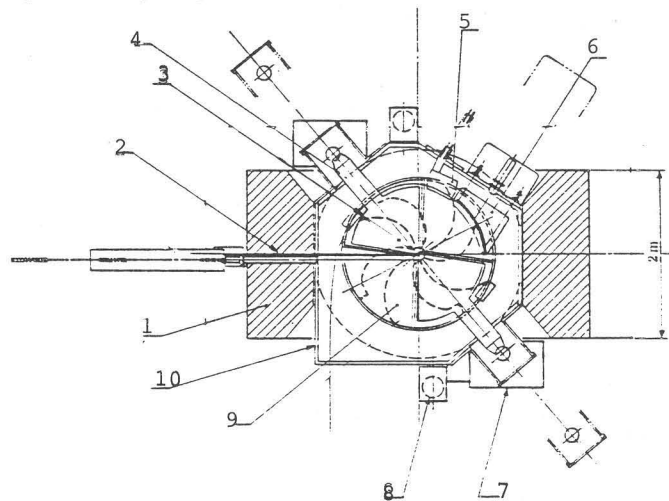
Layout in the cyclotron : Layout of each equipment inside the cyclotron is shown in fig.1, and its photopicture in fig.2.

The electromagnet is of a window frame type structure to facilitate the maintenance of the inside of vacuum box and the compact housing layout.

The accelerating system is comprised of two dees opposed diametrically, which are of triangular shape with 90° angle. Each dee is carried by a stem constituting a part of the associated resonant cavity

The vacuum box is an integral aluminium leak tight box with flanges for assembly of the cavities, the extractor, and other ancillaries. Circular openings of the same diameter

as the poles are provided in its top and bottom faces. The seals between vacuum box and pole are simply compressed by the weight of the top yoke. A special handling system allow to lift up the vacuum box using the electromagnet lifter to permit the exchange of o-ring of the lower pole. Vacuum is provided in the cyclotron by two high speed oil diffusion pumps.



- | | |
|-----------------------|----------------|
| 1. electromagnet yoke | 2. main probe |
| 3. dee | 4. cavity |
| 5. magnetic channel | 6. deflector |
| 7. power amplifier | 8. vacuum pump |
| 9. sector | 10. vacuum box |

Fig.1 : Layout of model 750PV cyclotron

For beam diagnostics the cyclotron is provided with a main probe.

The defining slit is carried at the end of a water cooled rod along the main probe. with this slit, the extraction efficiencies are improved by selection of the beam phase extension on the first turn.

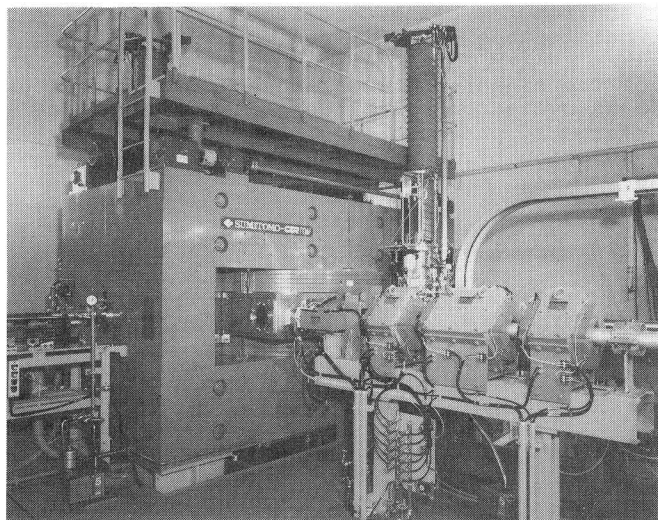


Fig.2 : Model 750PV cyclotron

The extraction system is comprised of an electrostatic deflector, a magnetic channel and a gradient correction system, to control the direction and shape of the extracted beam. The set of harmonic coils in the large radius region is used to introduce a first harmonic generating a coherent radial phase oscillation so that the separation between turns is improved when the beam reaches the electrostatic deflector.

There is a space for two internal target rods to be installed in this cyclotron.

Power supplies : Stabilized power supplies and electronic regulation circuits ensure stable operation with characteristics free of any temperature drift. All coils and high power circuits are water cooled.

Control system : The control system of model 750PV cyclotron is designed in order to conduct reasonably the operation, adjustment, and protection of the machine. The basic ideas of design are as follows.

1. The number of operating switches is reduced as much as possible, letting the operation simplified and avoiding miss-operation by means of the operating sequence guided by LEDs.
2. All of the operating status of the constituents of cyclotron are so arranged as to be displayed on CRT, letting the supervision of machine be facilitated.
3. Containing various kinds of parameters finally adjusted in a large amount of memories, and calling out them for being made available and setting of parameters is automated.
4. The controller of each constituent device has two operating mode provided, i.e., local and remote, being facilitated with easy maintenance of individual unit.
5. The signals between the controller devices and cyclotron constituent devices are isolated by photocouplers, so as to avoid malfunction by means of noises involvement.

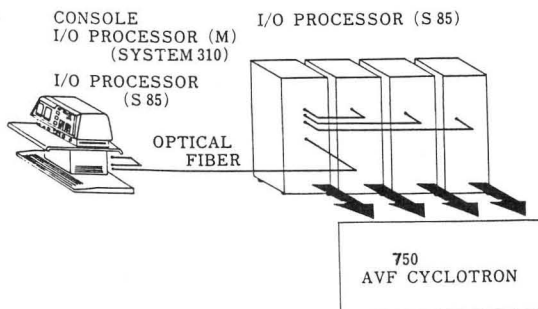


Fig.3 : Control system of cyclotron

6. Hardware are as much as possible standardized letting the number of kinds of the constituent parts be minimized so as to facilitate easy maintenance.

The hardware construction of controlling device comprises a unit of console and 9 sets of control racks. The console and four control racks are provided with built-in microcomputer system, being connected with serial transmission line between each other by means of optical fiber, as shown in fig.3. They execute all of transactions of necessary information for the operation of equipment.

On the other hands, due to their connection with cyclotron constituent devices through multicore cable each of the devices and equipment are facilitated with individual operation respectively.

Between each of the racks and constituent equipment and devices are provided with input/output through check pins for the purpose of maintenance's convenience.

The photopictures of console and control racks are shown in fig.4 and fig.5 respectively.

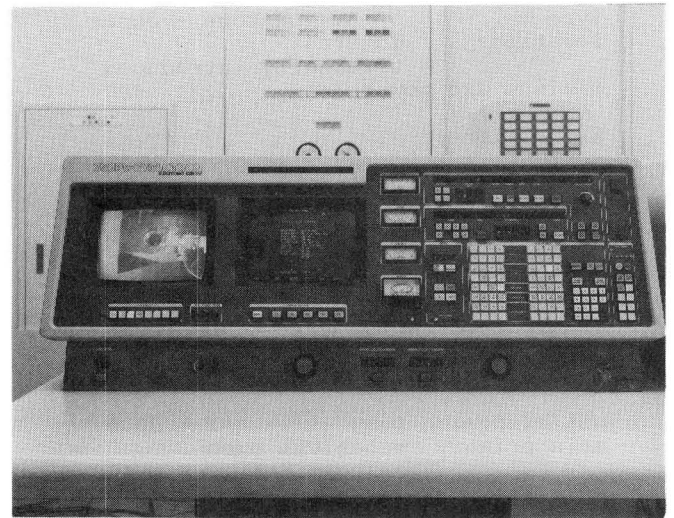


Fig.4 : Console

The main jobs of microcomputer system are as follows.

Processor (M)

- Filing of the parameter file-required for operation of cyclotron
- Displaying and printing out of the actual measurements and fault information per every 100 msec

Processor (A)

- Status display along with proceeding of sequence, and issuance of sequence command to (B)
- Man machine system in general, concerning the switches on the console

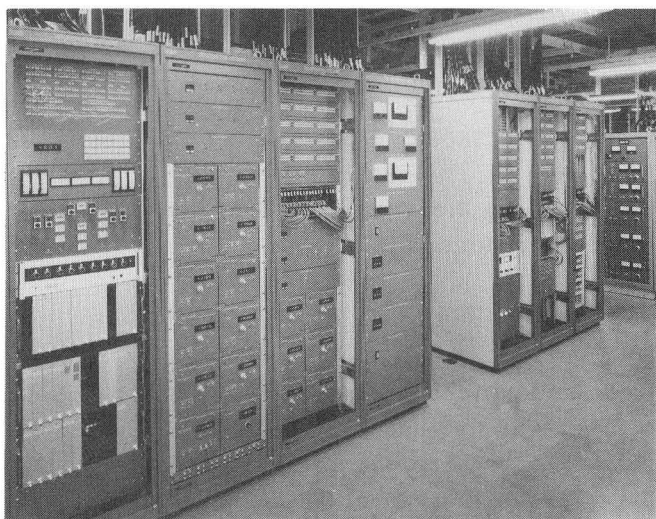


Fig. 5 : Control racks

- Compilation of setting parameters, and their revision and saving of the compiled parameters' (M), and loading from (M)
- Collection of fault information and its transferring to (M), concerning the actual measurements received from (B)

Processor (B)

- Executing start/stop and polarity exchange of each of the machines according to the specific sequence given by sequence commands from (A)
- Transferring the parameter set values to (C), (D), and (E), and compilation of fault information
- Automatic execution of stop sequence at fault occurrence

Processor (C), (D) and (E)

- Controlling the set value for each equipment
- Tempering of real measurements and status information from the equipment and their transferring to (B)
- Stability check of the real measurements sampled and accuracy check of positioning shall be executed, and the results shall be transferred to (B)

The cyclotron is operated by pushing five buttons (POWER, HI-VOL, BEAM, IRRAD, and TRANS) on a console panel.

Building requirement : Building requirements for model 750PV are summarized in table 4.

Table 4 : Building requirements

| | |
|-----------------------------|----------------|
| Cyclotron vault | |
| minimum inside dimensions | 7m x 8m x 5.5m |
| heat load | 20,000 kcal |
| thickness of shielding wall | 4 m |
| Power supply room | |
| minimum dimensions | 8m x 8m x 3m |
| heat load | 20,000 kcal |
| Control room | |
| minimum dimensions | 4m x 4m x 2.5m |
| heat load | 2,500 kcal |
| Power consumption | 350 kw |
| City water flow | 1,500 l/min. |