PRESENT STATUS OF BABY CYCLOTRON

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ABSTRACT

Ultra-compact cyclotron named as "BABY CYCLOTRON" developed by Japan Steel Works. Baby Cyclotron was designed to produce of short-lived isotopes such as C-11, N-13, O-15 and F-18 for clinical diagnosis. Prototype was completed in 1978 and was installed at NAKANO National Chest Hospital in Tokyo. After that, six machines have been delivered for Montreal Neurological Institute, Brookhaven National Laboratory in New York, Research Institute for Brain & Blood Vessels Akita, Kyushu University. Gumma University and NIKKO Memoreal Hospital and now make a great contribution to expand of nuclear medical reseach.

At present, K = 30MeV machine is under manufacturing for university of Pennsylvania.

On the one-hand, Baby Cyclotron have come to be utilized in various other areas such as to be used to analyze impurities in semiconductor substance by beam bombarding, study of new materials for nuclear fusion reactor and neutron source for Neutron Radiography Testing.

Photo 1 shows outlook of the Baby Cyclotron.

BABY CYCLOTRON FOR MEDICAL USE

Prototype was designed to accelerate of proton 10MeV and deuteron 5Mev. After that, we made three type machines which has enough ability to produce radioisotopes for clinical diagnosis, and special attention has been paid in derive features as follows:

1) Fixed energy and four sectors azimuthally varying field,
2) compact figure desired hospital's nuclear medical department,
3) A bitter type magnet yoke shielding activity,
4) Simple control and operation,
5) Easy maintenance without skilled personnel.

Performance ratings of Baby Cyclotron are shown in Table 1 and Table 2 show examples of our radioisotope production test with BC1710.

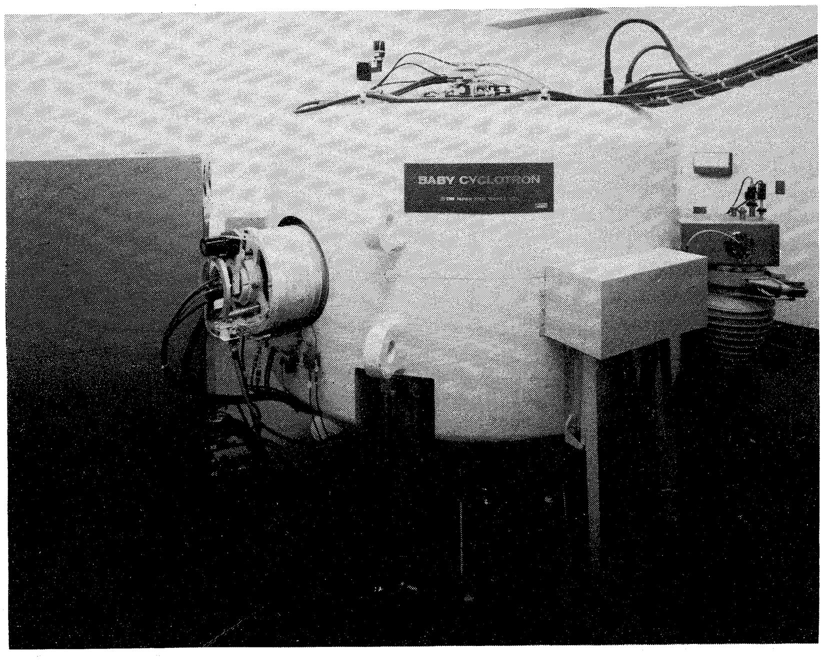

Photo 1 Outlook of the Baby Cyclotron

APPLICATION OF BABY CYCLOTRON TO OTHER AREAS

A Baby Cyclotron (BC168) delivered by us to Ibaraki Electrical communication Research Institute of the Nippon Telephone and Telegraph Public Corporation in March this year is unique system which can measure impurities in semiconductors in order of by the order of ppb and we got order Mini-cyclotron which can accelerate Proton, Deuteron, He-3, and α Particles from the Metal Materials Technical Research Institute of the Agency of Science and Technology for study new materials of nuclear fusion reactors that can withstand large quantities of neutrons with a high energy of 14MeV.

At present, studies are active on neutron radiography using Baby Cyclotron of energy 16MeV producing neutrons by the reaction of Be (p, n). We are conducting at our Muroran Plant the inspection of pyrotechnical products for the H-1 rocket which the National Space Development Agency is developing. Experimental layout is shown in Fig. 1.

A Baby Cyclotron is used to accelerate proton up to 16MeV with beam current of 50uA. These ions impinge upon a Be target to produce copious quantities of fast neutron. These fast neutrons are showed down to the thermal energy region with a polyethylene moderator surrounding the target. A portion of the thermalized neutrons are extracted from the target area by a collimator constructed with polyethylene boards.

Table 3 shows the typical results of the Baby Cyclotron-based radiography system for ASTM Indicators.

Photo 2 shows the differences of the radiographic images for X-ray and neutron from Baby Cyclotron.

Table 1 Performance Ratings of the Baby Cyclotron

		BC105	BC107	BC168	BC1710
Beam Energy (MeV)	Proton	10	10	16	17
	Deuteron	5	7	8	10
Beam Current (uA)	Proton	50	50	50	50
	Deuteron	50	50	50	50
AVF 4 Sector Magnet	Extraction Radius (cm)	30	30	37.5	42
	Pole Gap. Max. (cm)	9.5	9.5	12	13
	Min.	5.5	5.5	7	7
	Average Magnetic Field (T)	1.5	1.5(P) 1.8(D)	1.5	1.4(P) 1.5(D)
RF Accele-rating System	Dee	2 x 45°			
	RF Powered by	Master Oscillator			
	Frequency (MHz)	47&55	47&55	47	43.5&47
	Tuning Rough	Plunger			
	Fine	Compensator			
	Accelerating Voltage (KV)	30	30	30	30
Ion Source	Type	Hot Cathode Penning Type			
	Voltage (V)	-500	-500	-500	-500
	Arc Current (A)	3	3	3	3
Deflector	Type	Electrostatic (DC)			
	Voltage (KV)	-50	-50	-50	-50
Vacuum System	Pressure (Torr)	10^{-6}	10^{-6}	10^{-6}	10^{-6}
	Difussion Pump (/sec.)	200	450	700	2,000

Table 2 Radioisotope Production Test with BC1710

Isotopes	Half life (min.)	Reaction	Incident energy (MeV)	Beam current (μA)	Yield (mCi)	Chemical form
^{11}C	20	$^{14}N(p,\alpha)^{11}C$	16.0	50	3,600mCi/1h	$^{11}CO_2$
^{13}N	10	$^{12}C(d,n)^{13}N$	8.7	50	1,200mCi/30min	$^{13}N_2$
		$^{16}O(p,\alpha)^{13}N$	16.0	50	1,400mCi/30min	^{13}N-aqueous solution
^{15}O	2	$^{13}N(d,n)^{15}O$	8.7	50	2,400mCi/10min	$^{15}O_2$
^{18}F	110	$^{20}Ne(d,\alpha)^{18}F$	8.7	50	600mCi/2h	$^{18}F_2$

We are, at present, developing several automated synthesis systems of precursor and organic compounds labeled by short-lived radioisotopes.

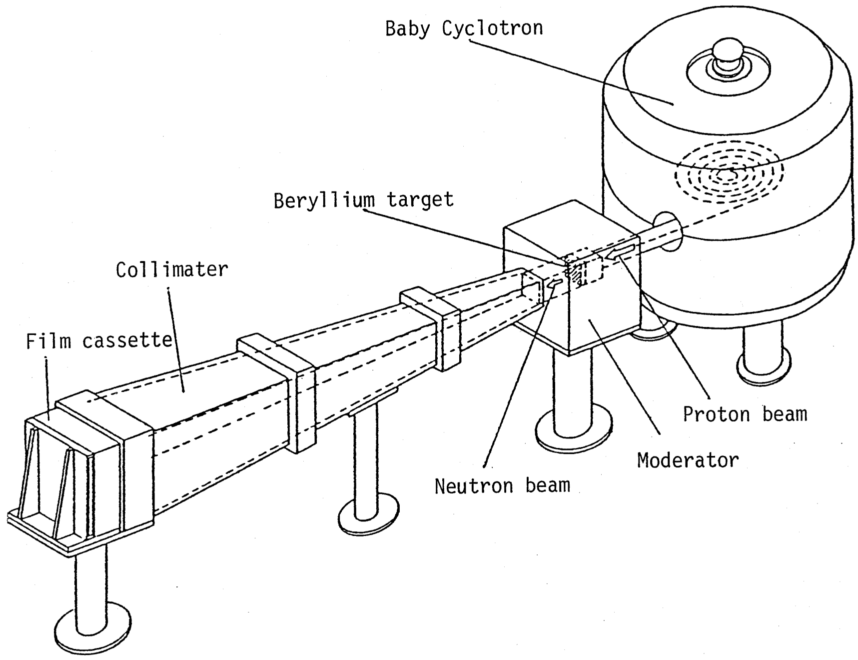

Fig. 1 Schematic Diagram of Neutron Radiograph Using Cyclotron

Table 3 Typical Results of the Radiography System for ASTM Indicatior

Type of cyclotron	BC168
Particle	Proton
Energy (MeV)	16
Beam Current (μA)	50
Target	Be
Collimator Length (mm)	2,600
Collimator Ratio (L/D)	50
Exposure Size (mm)	432 x 356
Converter	Gd
Neutron Flux at Object ($n/cm^2/sec$)	3.5×10^5
n/γ Ratio (n/mR)	3.3×10^5
Cd Ratio	5
Thermal Neutron Content (C%)	≧50
Scattered Neutron Content (S%)	≦13
Epithermal Neutron Content (E%)	≦4
Low Energy Gamma-ray Content (γ%)	≦2.5
Sensitivity Level (R)	≧10
Film	Kodak SR

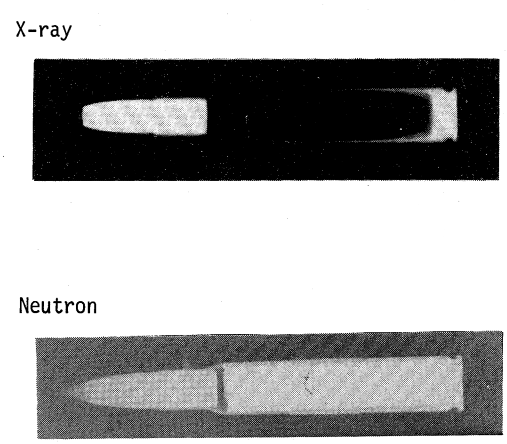

Photo 2 Differences of the Radiographic Images for X-ray and Neutron from Cyclotron

REFERENCE

1. E. Hiraoka et al. Ann. Report Radiation Center of Osaka Prefecture Vol.23, '82