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Suggested Session: S.5, S.6, S.7

THE EVALUATION OF A CW CYCLOTRON CAPABLE OF ACCELERATING IONS OF VARIOUS CHARGE TO MASS RATIOS

G. Bernard Rossi

The Crocker Laboratory 60" Cyclotron of the University of California is at present capable of consistently producing ion beams with the following specifications:

Ion	Energy (Mev)	Intensity (μa)
$(H)_2^+$	12	50 (deflected)
D_2^+	24	90 "
He^{++}	48	50 "
C^{+6}	>100	.1 (internal) .0001 (deflected)
N_{14}^{+6}	"	.1 (internal)
Ne_{20}^{+9}	"	.01 "
O_{16}^{+6}	"	.1 "

The wide range of usefulness of this cyclotron is the result of continued development of the unit since it was made operative in 1939, under the direction of Prof. E. O. Lawrence. This usefulness extends into many research fields including basic physics research into particle mechanics, nuclear chemistry research in the isotope studies of sub and transuranic elements, biological research involving tracer studies in animals and humans, neutron and ionizing particle irradiation effects on animals and cells, the physical chemical effects of ionizing irradiation of organic materials and the change in the physical property of materials after irradiation.

Operation of the cyclotron has been continuous over the past sixteen years with the exception of three major shutdown periods. Each of the shutdowns were planned to extend the usefulness of the cyclotron in the research fields mentioned above. The first such period extended from July 1944 to February 1945, the second

from April to November 1949, the third and current one from April to August 1954. The variations in beam specifications as a result of the shutdown, and intermediate developmental periods, are listed below:

	Ion	Energy (Mev)	Intensity (μa)
1944	$(H)_2^+$	8	100
	D_2^+	16	300
	He^{++}	32	<1
1946	H_2^+	9	50
	D_2^+	18	50
	He^{++}	36	3-5
1949	H_2^+	10	35
	D_2^+	20	50-75
	He^{++}	40	25
1955	H_2^+	12	60
	D_2^+	24	90-100
	He^{++}	48	50-75

The later shutdown period incorporated changes in the magnetic field shape with increased oscillator frequency range to permit acceleration of the O_{16}^{+6} ion and other ions not previously possible. During the test period subsequent to the shutdown, settings of the field and frequency were made corresponding to 50 and 52 Mev He^{++} particles. A gratifying amount of external beam was recorded (50 μa at 50 Mev) which allowed the photograph in Figure 1 to be made. This represents the circulating beam envelope within the dees from 15" to 25½". The horizontal marking to the right is a cross-section of the beam after deflection. Photographs of this type for the 52 Mev (8μa) particles indicated that the available dee voltage was less than threshold requirements for full acceleration.

Development of basic units required for efficient operation have paralleled the shutdown changes. These included ion source research, deflecting mechanism development, improvement of dee "feeler" geometry, beam recording devices, oscillator

stabilizing units, methods for bombarding targets, the removal of the beam from the magnetic field and many others.

It is possible at present to utilize the various ions at different locations along their trajectory. Internal bombardments at intensities of 200 μa can be made of relatively thin foils; bombardments at the external location can be made on powdered, liquid, gaseous and solid materials; scattering work can be performed at a distance of 21' from the machine with the aid of strong focussing equipment; fast neutron irradiations (6-7 Mev average energy) can be made at various locations. A recent development has been to permit bombardments at a location within the vacuum chamber about 1 foot from the deflector channel termination. At this point, beams of 215 $\mu a/cm^2$ have been utilized for rare material bombardments. A considerable number of engineering problems had to be overcome before such work could proceed.

Much worthwhile research has been accomplished by users of this cyclotron. Included among these are the production of sufficient amounts of plutonium for the original study of its chemical and physical properties; the discovery of elements 85, 93, 94, 96, 97 and 98; the original production of some 150 radioisotopes; neutron therapy of advanced states of human cancer; the principal production of radio-phosphorus for the treatment of the leukemias and polycythemia vera; radio-iodine production for the clinical treatment of hyperthyroidism in man; the acceleration of the first useable quantities of ions heavier than helium; a large amount of research in physics, chemistry, biology and medicine as published in the various journals.

The performance of this cyclotron is a credit to a number of persons who have been staff members over the sixteen year span. Dr. J. G. Hamilton, director of Crocker Laboratory since 1948, has been associated with the 60" Cyclotron since 1939; the author a member of the staff since 1943. The 60" Cyclotron staff members assisting in the planning, design and execution of the last expansion program include W. B. Jones, C. A. Corum, K. D. Jenkins and

an operations crew of ten members. These efforts, augmenting others preceding them, have led to an operating efficiency of 80 to 85 per cent of available time.

This work was done under the auspices of the U. S. Atomic Energy Commission.

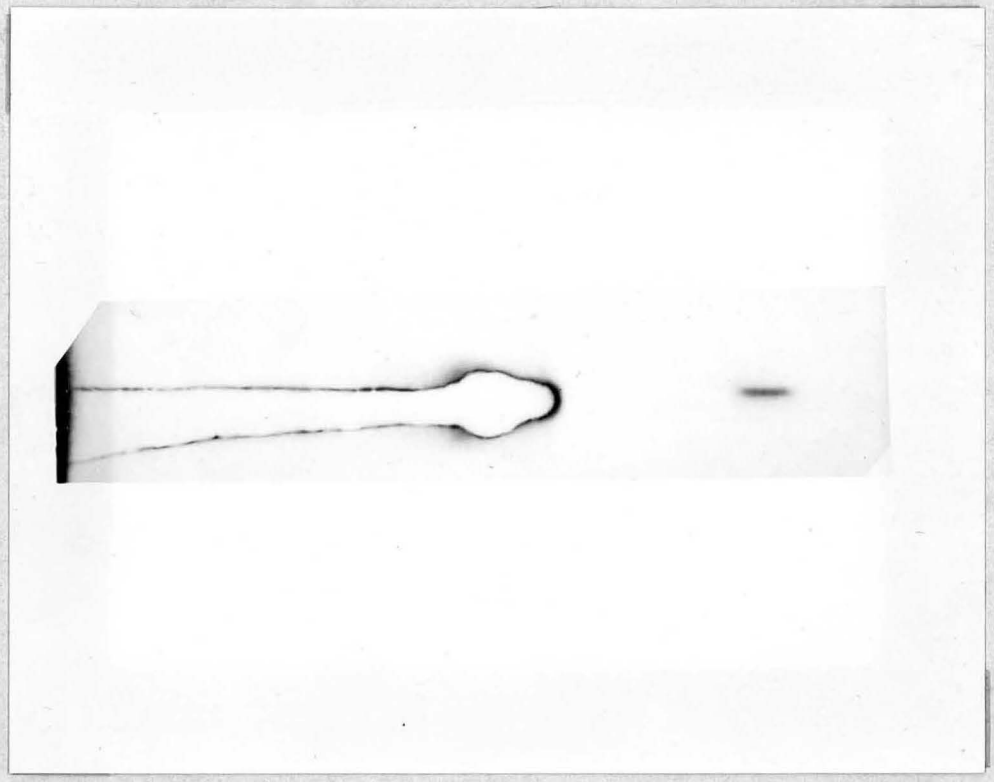

Fig. 1