APPENDIX

CATALOGUE OF ISOCHRONOUS CYCLOTRONS

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(Not presented)

From previous tabulations and correspondence and through conversations during the Conference, the list of isochronous cyclotrons now includes 44 projects; the detail specifications are tabulated below. The list includes 15 machines in operation, 11 under construction, 7 in engineering and design, and 11 studies and proposals still awaiting funding.

The first operating isochronous cyclotrons were, of course, remodeled conventional machines. These are rapidly being followed, however, by new and larger cyclotrons specifically designed to extend isochronous operation to energies previously inaccessible to fixed-frequency machines, and usually to provide the advantages of variable energy. There are four proposals for high-intensity isochronous cyclotrons in the 500 - 850 MeV energy range, to be operated as meson factories. At present, however, there appears to be no active interest in the 100 - 500 MeV range.

Apparently, medium-energy cyclotron designers are beyond the model building stage. Only one development model is under construction, and all projects at the engineering design, study, and proposal levels are for full-scale research machines.

This tabulation includes only those cyclotrons in which the magnetic field is designed to provide isochronism, that is, machines with radially increasing average magnetic fields and with azimuthal field variations to provide the focusing forces. Not included are a few conventional cyclotrons in which simple Thomas shims or AVF coils have been introduced to provide some axial focusing. Examples are : the 70-inch Cyclotron de Saclay, the 52-inch Markle Cyclotron at MIT, and the Los Alamos Variable Energy Cyclotron.

The rapid strides in the art and science of accelerator design, in general, are impressively demonstrated by the sophistication of the new generation of cyclotrons described at this Conference, especially when one recalls that an early paper on linear accelerators[1], published only 35 years ago, was cited by E.O. Lawrence[2,3] as the initial stimulus in his accelerator career - and when one further observes that the author of that early paper is a fellow participant in this Conference.

References

1. R. Wideröe, Archiv für Electrotechnik 21, 387 (1928).
2. E.O. Lawrence, "The Evolution of the Cyclotron", Le Prix Nobel en 1951, p. 127.
3. M.S. Livingston, "History of the Cyclotron", Physics Today 12, 18 (1959).

(*) Operated for the USAEC by Union Carbide Corporation.

ISOCHRONOUS CYCLOTRONS, SPECIFICATIONS

		Status	Energy (MeV)	Beam, Goal: Int (μA)	Beam, Goal: Ext (μA)	Beam, Goal: Orbit, r max (cm)	Magnet: Pole dia (cm)	Magnet: Gap min (cm)	Magnet: Sect	Magnet: Spiral max (°)	Magnet: AVF Coils (pr/sect)	Magnet: Circ Trim Coils (pr)	Magnet: Av Field at r max (kG)	Magnet: Total Power (kW)	RF System: Dees (No, °)	RF System: Dee Apt (cm)	RF System: RF (Mc/s)	RF System: Power max, in (kW)	RF System: Energy Gain, max keV/turn	Dee Tuning	Comments
Canada	Winnipeg	Const (1964)	≦50p*	100	1	53	117	2.5	4	49	0	0	20	120	2, 45	2.5	14–29	50	100	MS	Temp reg Invar shims
CERN	Geneva	Study	850p	100		437			8	60			12				9.4			FF	Meson factory
France	Grenoble	Eng (1966)	≦60p*	200	20	80	200	14	4	45	3	9	15	250	2, 90	4	10.5–21	60	120	MP	CSF machine
	Orsay	Const (1965)	≦30p*	200		47	110	16	4	35	0	0	17	250	1, 180	4.5	10–25.2	100	200	MS	Alloy shims
	Orsay	Const (1963)	≦68α*	1000		85	200	21	3	0	5	0	14.3	400	1, 180	5	4–10.5	300	300	MS	Alloy shims
	Saclay	Const (1963)	≦25p*	100	20	56	120	14	3	35	3	11	15	140	1, 180	2.5	7–22	85	100	MS	Philips machine
Germany	Julich	Eng	≦90d	50	10		320	6	3	Yes					3, 60				300		AEG study
	Karlsruhe	1962, in use	50d	100	10	107	225	8	3	0	5	0	14.7	30	3, 60	4	33	70	240	FF	AEG machine
India	Calcutta	Study	≦25p*																		Would be purchased
Italy	Milan	Const (1964)	≦45p*	100	10	70	166	11	3	0		8	14.1	200	1, 180	3.6	17–22	120	140	MP	Pole tips contoured
Japan	Osaka	Study	≦40p*	500	50	62	140	15	3		2	7	16		1, 180	3.5	7.5–22.5	120	160	MS	
Netherlands	Amsterdam	Const (1964)	≦25p*	100	20	56	140	15	3	45	3	11	15	140	1, 180	2.5	7–22	85	100	MS	Philips machine
	Delft	1958, in use	12p	500		34	86		4	0	0	0	14		1, 180	5.6	21		25	FF	1st isochronous cyclotron
	Eindhoven	1963, in use	≦25p*	100	20	56	120	14	3	35	3	11	15	140	1, 180	2.5	7–22	85	100	MS	Philips prototype
	Eindhoven	Const (1964)	27p			57	142	16	3	48			13.4		1	3	20		100	FF	Philips; isotope production
	Groningen	Design (1968)	≦50p*	100	10	115	280	25	3 or 4			10	14	300	1, 180	4	5–15	300	140		Philips machine
Switzerland	Zurich	Study	500p	100		490	1000	8	8	25	7		7.5	400	4 cav	5	60	400	1000	FF	Injection at 70 MeV
USSR	Alma Ata	Design					150														
	Dubna	1959, in use	13d	20		53	120	8	6	75			14	55	1, 180	4	10.4	15	70	FF	
	Leningrad	Const (1963)					69		3	Low							7–21				
	Moscow	1961, in use	≦32d*	300	70	69	150	16	3	0	1	6	16.7	200	2, 180	5.8	7.8–13	120	280	MS	Converted 1.5-m machine
UK	Amersham	Design	27p			57	142	16	3	48			13.4		1, 180	5.6	21			FF	Philips machine
	Birmingham	1961, in use	≦11d*	1000	250	46	102	7.6	3	0	2	8	15.8	40	1, 180	2.5	7–16	45	60	MS	Ions injected axially
	Harwell	1959, in use	3p	1000		20	56	10	3	0	0	12	13	100	1, 180	5	15–20	20	60	MS	Model of 70-in.
	Harwell	Const (1964)	≦50p*	500	50	76	178	19	3	42	3	12	17	750	1, 180	4.1	7.2–23	445	200	MS	
USA	Ann Arbor	1963, in use	≦37p*	1000	250	93	211	17	3	43	0	12	15	200	2, 180	3.2	6–16	360	280	MS	Beam testing (April 63)
	Argonne	Study	≦70p*		200			19	3	60		17	17		1, 180	3.8	6–20			MP	
	Berkeley	1961, in use	≦60p*	1000	100	99	224	19	3	56	5	17	17.1	1036	1, 180	3.8	5.5–16.5	350	140	MP	
	Boulder	1962, in use	≦30p*	1000	100	60	132	12	4	45	5	1	13.2	100	1, 180	3.8	7.5–21.3	100	150	MS	Deflecting H^- ions
	Brookhaven	Design	≦42p*	300	50	64	152	19	3			8	14.65	200	1, 180	4.8	9–27	150	200	MP+MS	Conversion of 60-in.
	Claremont, Cal	1960, in use	2.5p	25		25	58	10	6	0	0	0	9	3	1, 180	2.5	13.9	2.5	34	FF	For undergraduate instruction
	Davis, Cal	1962, in use	≦12p*	400	100	25	60	4.4	3	45	1	9	19.7	45	2, 110	1.5	15–30	20	100	MS	
	Davis, Cal	Design (1965)	≦75p*				193		3	30	1	10			1, 180		7.5–22.5			MS	Old 60-in. Crocker magnet
	E. Lansing	Const (1964)	≦50p*	1000	500	71	163	17	3	0	0	8	14	140	2, 144	4.4	13.5–21.5	240	270	MP	Double mode RF
	Los Angeles	1960, in use	≦50p*			51	125	2.5	4	47	0	8	20	120	2, 45	2.5	26.5–29		90	MP	Deflecting H^- beam
	Los Angeles	Study	700H⁻	170	150	1036	1113	76	6	78	4	17	3.1	3500	2, 180	20	11.31	1780	400	FF	To accelerate neg ions
	Maryland	Proposed	≦75p*	1000	200	99	224	19	3	56	6	17	17	460	1, 180	4.1	6–19.5	100	140	MP	Brobeck Eng
	NRL (Wash)	Proposed	≦75p*	1000	100	80	193	19	3	30	4	10	17.2	2000	1, 180	4.8	7.5–22.5	650	200	MS	Horizontal "ORIC"
	NRDL (San F)	Eng (1965)	≦100p*	1000		84	178	5	4	56	5	9	18	300	2, 35	2.5	10–30	205	300	MS	Movable iron shims
	Oak Ridge	1962, in use	≦75p*	1000	100	80	193	19	3	30	4	10	17.2	2000	1, 180	4.8	7.5–22.5	650	200	MS	Vertical med plane
	Oak Ridge	Proposed	810p	200	100	584			8				18			10	13.7 or 20.6	<800	1000	FF	Model testing
	St Louis	Const (1963)	≦30p*	1000	100	58	137	15	3	Low	4	5	14	150	1, 180	3.2	7.5–22.5	120	120	MS	Conversion of 45-in.
	Texas A&M	Proposed	≧100p*	1000	100	99	224	19	3	56	5	17	13.2	2000	1, 180	3.8	8–24	650	150	MP	Copy of LRL 88-in.
	Urbana	1958, in use	≦15p*	500	50	47	111	14	4	$\tan^{-1} .13r$	1	5	15.7	98	1, 180	3.8	9–18.5	100	180	MS	Conversion of 50-in.

*Also other ions.
MS Movable short
MP Movable panels
FF Frequency fixed.

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ORNL May 17, 1963