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Title
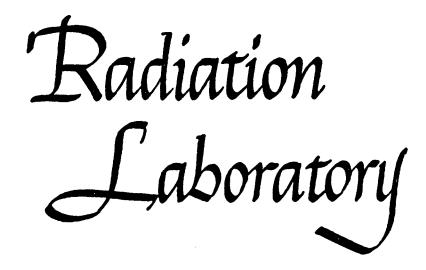Synchrotron Specifications

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SYNCHROTRON SPECIFICATIONS

Craig Nunan, George Farly

December 6, 1949

Berkeley, California

SYNCHROTRON SPECIFICATIONS

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GENERAL

Peak magnetic intensity at synchronous orbit	oersteds	11,400	M*
Nominal value of "n" (magnetic field exponent)	oersteds	2/3	M
Radius at "n" = 1	inches	41.7	M
Synchronous orbit radius	inches	39.4	C
Target radius	inches	37.8	M
Radius at injector filament (approx.)	inches	41.0	M
Distance between injector filament and tip of injector	inches	0.140	M
Vertical aperture of donut	inches	2-5/8	M
Horizontal aperture of donut	inches	5-3/8	M
Energy of electrons at injection	Mev	0.1	M
Magnetic intensity at injection	oersteds	11.2	C
Time from injection to end of betatron cycle	μsec.	100	M
Energy at end of betatron cycle	Mev	2.0	C
Value of "β" at end of betatron cycle	v/c	0.98	C
Magnetic intensity at end of betatron cycle	oersteds	82	C
Number of revolutions during betatron cycle		3,800	C
Time required for acceleration to full energy	μsec.	7,940	M
Number of revolutions during total acceleration		380,000	C
Distance traveled during total acceleration	miles	1,500	C

* (R) - Rating
  (M) - Measured value
  (C) - Calculated or estimated

SYNCHROTRON SPECIFICATIONS

Maximum electron energy at end of r.f. acceleration	Mev	341	C
Loss of energy by radiation while electrons spiral in to target after r.f. pulse	Mev	6	C
Time from end of r.f. pulse until electrons spiral in to target	μsec.	120	M
Duration of electron beam collision with target (This can be lengthened to as much as 2500 μsec by controlling the r.f. voltage pulse shape)	μsec.	10	M
Maximum energy of electrons on striking target	Mev	335	C
Operating pressure for 1/2 attenuation of x-ray beam	microns	.035	M
Resonant frequency of capacitors and magnet after saturation of flux bars	cycles/sec.	32.1	M
Number of magnet pulses per second (normal operation)		6	M
Personnel protection - concrete walls 4 ft. thick, 235 #/cu. ft.			M
Maximum x-ray beam intensity as measured by ionization chamber behind 1/8 in. of lead	roentgen/hr.	3,400	M

Betatron beam monitor consists of an anthracine crystal on one end of a 15-1/2 in. long, 1 in. diameter lucite rod and a 1P21 photomultiplier on the other end. The crystal is covered with 2-1/2 mil aluminum and the lucite rod is coated with air-drying silver paint. Electrons which the r.f. voltage fails to catch spiral in to strike the anthracine crystal and the scintillations are detected by a photomultiplier and observed on an oscilloscope.

Target - platinum bar, 1-1/4 in. long, 1/4 in. wide (normal to electron beam path) and 20 mils thick (thickness beam electrons traverse), placed in front of betatron beam monitor.

Synchrotron x-ray beam monitor - ionization chamber behind 1/8 in. of lead, placed 18 ft. from the platinum target.

SYNCHROTRON SPECIFICATIONS

MAGNET

Dimensions of magnet	inches		
Length		194	M
Width		92	M
Height		98	M
Mean gap		3.7	M
Useful width of field $0 < n < 1$		4-3/4	M
Weight of iron (29 ga. transformer iron, Type 52)	tons	135	M
Lamination thickness	inches	.014	M
Flux bars	number	18	M
Dimensions: length	inches	78	M
width	inches	5	M
depth	inches	2-3/8	M
Laminations: Armco electrical steel			
thickness	inches	.002	M
number per bar		960	M
Pole piece segments (number for two poles)	number	80	M
Laminations: #58 trancor steel			
thickness	inches	.014	
number per segment		180	
Weight of copper	tons	1-3/4	M
Nominal value of "n"		0.67	M
Coil resistance	75°C ohms	.0105	M
Length of coil	inches	10,250	C
Cross section of copper	inches^2	1.07	C
Diameter of individual strands	inches	0.0641	M
Number of strands		331	M

SYNCHROTRON SPECIFICATIONS

MAGNET (Continued)

Strand Formex insulation thickness	inches	1.3×10^{-3}	M
Thickness of cable insulation	inches	.080	M
Outside diameter of cable	inches	1.611	M
Total flux, peak	Maxwells	3.04×10^{8}	C
Magnemotive force, peak	ampere turns	98,000	C
Ampere turns per gauss		7.8	C
Volts per turn, peak		594	C
Number of turns in magnet coil		32	M
Peak volts		19,000	M
Peak current	amperes	3,060	C
Reactive power	kva	29,200	M
Repetition rate	pulses/sec.	6	M
Power dissipated in oscillatory circuit at 6 pulses per second and 32.1 cycles per second	kw	74	C
Iron loss	kw	8	C
Copper loss	kw	8	M
Capacitor a.c. loss	kw	32	C
Ignitron loss	kw	26	C
Energy dissipated per cycle	kw-sec	12.3	C
Energy stored in capacitors	kw-sec	148	M
$Q = 2\pi$ x energy stored/energy diss. per cycle		76	C
Total capacity	μfd	818	M
Magnet inductance (no flux bars)	mH	30.0	C
Rate of change of guide field at injection	oersteds/μsec	.7	M
Maximum rate of change of guide field after flux bar saturation	oersteds/μsec	2.3	C

SYNCHROTRON SPECIFICATIONS

MAGNET (Continued)

D.C. power in capacitor bleeder resistors	kw	13	M
D.C. power in current limiters between rectifiers and capacitor bank	kw	10	M
Total power delivered by rectifiers	kw	97	C

AUXILIARY MAGNET WINDINGS FOR FIELD ADJUSTMENTS

(a) 16 one-turn compensating coils, one around each 1/8 of   2U 3634

the pole tip, top and bottom, each connected to a

selsyn-controlled resistance.

(b) 16 one-turn "n" coils of #18 flaminol wire, each coil

concentric with the orbit, 8 on each pole face, with

radii from 36-1/4 in. to 42-1/2 in., each connected to

a resistance variable from 200 to 4,200 ohms.

(c) Magnet bias winding - 8 turns of #8 rockbestos cable   2U 3733

around the outside of the main magnet windings, supplied

from storage batteries via a 1/2 H 102 amp choke and 2

ohm rheostat.

(d) Flux bar bias winding - two turns in parallel of 4/0   2U 3722

cable around the group of 18 flux bars, connected via   2U 3564

a 2 mH 400 amp choke to a 1-1/2 kw, 7-1/2 volt d.c.

generator

(e) Booster winding - one turn of #8 rockbestos cable around   2U 3881

the group of 18 flux bars, connected via a 5C22 to a choke

and condenser which provide a half sine wave pulse variable

from 67 to 437 μ sec. duration and 0 to 5 kv.

SYNCHROTRON SPECIFICATIONS

AUXILIARY MAGNET WINDINGS FOR FIELD ADJUSTMENT (Continued)

(f) Inductance winding - one turn of #8 rockbestos cable
around the group of 18 flux bars, connected to an air
core inductance which can be adjusted remotely from
0 to 7 mH in steps of 1/16 mH.

(g) Contractor coil - an upper and a lower pole compensating   2U 4462
coil connected in series via a 3C45 thyratron to a pulse
line which produces a 400 volt spike approx. 0.2 μ sec long.

MAGNET POWER SUPPLY

		2U 2155 2U 2225		
Input power 3 phase (approx.)	kva		130	M
Input voltage	volts		480	M
Input current	amps		160	M
Induction regulator (Type IRT)	kva		65	R
Input	volts		480	R
Output range (73% buck/boost)	volts		130-830	R
Maximum current per phase	amps		105	R
Rectifier transformer (W) Type SL 2 in parallel	kva		50 ea	R
Primary voltage Y	volts		830	R
Output voltage Δ Tap #1	volts		11,535	M
Tap #2			13,460	M
Used as of Tap #3			15,380	M
6-1-49 Tap #4			17,300	M
Tap #5			19,235	M

SYNCHROTRON SPECIFICATIONS

MAGNET POWER SUPPLY (Continued)

Rectifier tubes - 3 phase - full wave

Tubes - GL 857B		6	
Maximum voltage	volts	22,000	
Maximum current	amps	40	
Average current	amps	10	
Cooling - forced air			

Filter choke - GE type

Inductance	henry	60	R
Peak current	amps	10	R

Current limiters (2-562 tubes in parallel)

Peak forward voltage	volts	60,000	R
Peak plate current	amps	7.5	R

Average d.c. output

Voltage at rectifiers (6 pulses/sec.)	kvolts	20.8	C
Current (6 pulses/sec.)	amps	5	M

IGNITRON CONTACTOR

2U 2155
2U 2225

Number of ignitrons		4	
Type of ignitron	GL-506		
Peak forward volts per tube	volts	20,000	R
Max. current per tube (as rectifier)	amps	900	R
Max. average current per tube	amps	150	R
Cooling water required per tube	gal/min.	5	R
Average plate current per tube	amps	91	C
Peak plate current per tube 32.1 cycle resonance	amps	1,530	C

SYNCHROTRON SPECIFICATIONS

CAPACITOR BANKS

Total series capacity	μfd	818	M
Capacity each bank		1,636	M
GE 460 volt 15 kva 3 phase power factor correction cap.	total no.	2,688	M
Connected for 10 kva single phase (approx. 125 mfd) 24 racks, 112 capacitors per rack			
W 1 μfd 25 kv d.c. capacitors in 8 racks of 80 per rack	total no.	640	M
Total reactive power @ 19 kv and 60 cps	kva	55,800	C
Total reactive power @ 19 kv and operating frequency of 32.1 ∼	kva	29,800	
Scaler-pulser, synchronous with 60 cycle power line but with phase adjustable over 360 degrees. Available from 6 pulses per second to one pulse every 9.6 seconds. Supplies a 70 volt, 300 μ sec. pulse to GL 414 thyratrons which fire the leading ignitrons. An adjustable delay is used to fire the trailing ignitrons just prior to reversal of magnet current.	2U 1784		

RADIOFREQUENCY ACCELERATION   2U 2165

R.F. gap voltage at which beam is lost	kv	1.2	M
R.F. gap voltage at which gap arcs over	kv	3.5	M
Oscillator plate voltage for maximum gap voltage	kv	4.0	M
Oscillator output during pulse at 3500 gap volts	kw	6	M
Average d.c. power to oscillator at 3500 gap volts	kw	.5	M
Nominal frequency	mc/sec.	47.7	M

SYNCHROTRON SPECIFICATIONS

RADIOFREQUENCY ACCELERATION (Continued)

Maximum frequency	mc/sec.	50.4	M
Minimum frequency	mc/sec.	44.6	M
Nominal r.f. pulse length	μsec.	7,840	M
Maximum r.f. pulse length	μsec.	13,000	M
Minimum r.f. pulse length	μsec.	10	M
Characteristic impedance of resonator	ohms	5.7	C

OSCILLATOR AND OSCILLATOR SUPPLIES   2U 2165

Oscillator tube - Eimac 3X2500 A3

Maximum d.c. plate volts	volts	5,000	R
Maximum d.c. plate current	amps	2	R

Oscillator hv power supply

Input - 3 phase	volts	240	R
Output voltage maximum	volts	10,000	R
Maximum charging current to capacitors	amps	2.5	R

Filter

Choke   2 henry @ 4 amp

Capacitors   30 μfd @ 10 kv

INJECTION   2U 2745

Injection energy, maximum	kv	100	M
Injection pulse length	μsec.	2	M
Injector pulse transformer	2U 3872		

Injector tungsten filament RMS

current	amps	6	M
voltage	volts	3.5	M

SYNCHROTRON SPECIFICATIONS

VACUUM		2U 3683 2U 1064	
Total cubic footage under evacuation including tank and headers	ft.^{3}	2.75	C
Oil diffusion pumps - distillation products type MC 500	number	2	M
Input power	watts	1,000	R
Cooling water required	gal/min.	1/6	R
Mechanical pump - Kinney 5 hp	number	1	M
Capacity	cfm	500	R
(This pump for roughing use only.)			
Mechanical pump - Kinney 1/2 hp	number	2	M
Capacity	cfm	25	R
(One backing up each oil pump above.)			