



Fermilab

\bar{p} Note #364

Debuncher and Accumulator Kickers

T. Castellano

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DEBUNCHER AND ACCUMULATOR KICKERS

There are 5 kickers in total in the two rings. \bar{p} Note 321 by J. Petter (6/83) describes the three Debuncher kickers in depth, consequently I will only discuss the two Accumulator kickers, injection and extraction. Refer to Table I for a summary of parameters for all 5 kickers.

Accumulator Injection and Extraction Kickers

These two kickers are identical in design. The injection kicker fall time determines the design almost completely. They are ferrite, single turn, delay line type magnets with an eddy current shutter to prevent disturbance of the stacked beam during injection or extraction. The need for a shutter requires that the entire magnet be enclosed in a vacuum tank. This precludes the possibility of building a conventional delay line type magnet (where ceramic capacitors are distributed along the magnets length to "match" the magnet inductance to the system impedance), this is because the capacitors would have to be placed in the vacuum also and would present an outgassing problem. Instead we chose to build parallel plate capacitors into the magnet design, using vacuum as our insulation. SPICE circuit analysis calculations demonstrated that in order to keep reflected voltages low each magnet would have to be broken down into at least 8 sections each with its own capacitance in parallel. Choosing the impedance of kicker is a trade off between propagation delay $t_d = \sqrt{LC} = L/Z_0$ (i.e. minimum rise or fall time) and operating voltage, $V = IZ_0$ to achieve the field needed for the required kick. Since 25Ω was considered optimum a quick calculation showed that very large area capacitor plates would be needed to achieve the desired capacitance. Consequently a dielectric (ceramic, $\epsilon_r = 10$) reduced the linear dimensions of the plates by about a factor of 3.



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	Debuncher Injection (Proton)	Debuncher Injection Antiproton	Debuncher Extraction	Accumulator Injection	Accumulator Extraction
Rise time maximum	—	—	190 ns	—	500 ns
Fall time maximum	205 ns	—	—	75 ns	—
Pulse width minimum	1.49 μ s	—	1.5 μ s	1.5 μ s	1.5 μ s
Kick needed	6.1 mr	6.1 mr	4.6 mr	4.0 mr	4.0 mr
Deflection due to kick (Sagitta)	10 mm	—	5.5 mm 6 mm	6.5 mm	—
Horiz. or Vert. Kick ?	VERT upward	VERT upward	Horiz. inward	Horiz. inward	Horiz. inward
SB dl needed	1.81 kg-m	—	1.34 kg-m	1.19 kg-m	—
Magnetic Length	2.77 m	2.77 m	2.34 m	2.24 m	2.24 m
Field needed (B_0)	650 gauss	—	574 G	531 G	531 G
Aperture V x H	56 x 42 mm	56 x 42 mm	42 x 75 mm	30.5 x 250 mm	—
Beam Size V x H	32 x 32 mm	—	35 x 70 mm	See S-5 of Sept 83 Design Report	—
Ferrite Gap Size V x H	65 x 50 mm	—	52 x 84 mm	30.5 x 57.15 mm	—
Ferrite Type	Ceramic Magnetics CMD500S $\mu_r = 1200$			Ferroxcube 4C6 $\mu_r = 125$	
Impedance	10 Ω	10 Ω	12.5 Ω	25 Ω	25 Ω
Current at B_0	2530 Amps	—	2420 A	1400 Amps	—
Voltage at B_0	25.3 kV	—	30.2 kV	35 kV	—



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	Debuncher Injection (Proton)	Debuncher Injection (Antiproton)	Debuncher Extraction	Accumulator Injection	Accumulator Extraction
# of "modules" per magnet	3	3	3	3	3
inductance per module.	1.52 μ H		1.55 μ H	1.73 μ H	
# of capacitors / value of each per module	24 / 630 pF		20 / 500 pF	18 / 150 pF	
\sqrt{LC} prop delay per module	150 ns		125 ns	62 ns	
Flange to Flange length	125 $\frac{1}{8}$ "	125 $\frac{1}{8}$ "	107 $\frac{7}{8}$ "	122.8025"	
Location (between Quads)	D2 Q2 D2 Q3	D4 Q2 D4 Q3	D6 Q9 D6 Q10	Acc Short Straight Section A-20	
End Flange Type					

Comments

- 1) Accumulator injection and extraction magnets are identical, vacuum gap capacitor, shuttered magnets. The injection kicker is split into 3 modules each powered separately, therefore the total fall time is equal to that of 1 module. The extraction kicker however has all 3 modules connected in series, it has a rise time of about 3 times the propagation delay of one module.
- 2) The debuncher injection kickers for p's and \bar{p} 's are identical except we plan to power the \bar{p} injection kicker modules separately, and the p injection kicker modules in series, thereby slowing the fall time as above. This is done to reduce costs, this magnet is used only during commissioning.

Since the fall time of the magnetic field must be 75 ns or less in the Accumulator injection kicker and the propagation delay increases linearly with length for a given gap size, the magnet was split into 3 separate "modules", each with its own power supply and a td of 66 ns. The extraction kicker need not be nearly as fast and has its three "modules" connected in series and powered by one supply.

Power Supplies

The ideal waveform for the current through a kicker is a perfectly sharp edged square wave. A close approximation to this can be achieved by charging a length of coaxial cable to twice the voltage needed and using a high voltage switch (thyatron) to discharge the cable into a matched resistive load. Since the accumulator injection kicker needs a pulse width of about 1.5 μ s this requires about 500 feet of cable. Consequently the pulse emerges from it slightly distorted with a "tail" after the initial pulse. This increases the fall time, but a second thyatron switch which "clips" this residual tail by shorting it to ground can be used to restore the square shape. SPICE circuit simulations lead us to believe that a 40 ns or better fall time of the current through the magnet will lead to a 75 ns or less fall time of the field. A practical lower limit is 20 ns which is the intrinsic rise time of thyatrons at these current levels.

Shutter

The shutter is a pivoting device, the blade is 5 mm thick aluminum and is supported by I-sectioned titanium arms. A vacuum seal at the pivots is provided by flexible bellows and the entire mechanism is driven by a stepping motor and

crank arrangement.

Vacuum

A vacuum of 10^{-10} torr must exist inside the kicker vacuum tank. Since the capacitor plates, dielectric ferrites and shutter parts present a great deal of surface area, a large number of pumps are required. There will be one ion pump and five titanium sublimation pumps mounted directly on the kicker vacuum tank.

Cast of Characters

L. Bartoszek

J. Funk

M. Kucera

J. McCarthy

L. Sobocki

G. Termansen

E. Tilles