Fermilab

LBNF Kicker Capacitor Specification

DRAFT

	Date	Organization	Extension
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1. Scope

This specification covers the requirements for the pulse capacitors for the Long Baseline Neutrino Facility, Extraction Kicker Magnets.

The kickers magnet will be located inside an accelerator enclosure and the capacitors are inside the magnets. The capacitors will be arranged into 28 banks of 1,400 pF each.

The capacitors are part of a pulse forming network. The magnet voltage has a peak of 27 kV with a 200 ns rise and fall time, 11 µs flattop.

The capacitors will be pulsed approximately once per 1.2 seconds with an expected lifetime of 100,000 hours (3*10^8 pulses continuous duty). To meet this lifetime, in Fermilab experience with ceramic capacitors, the operating voltage should be no more than 2/3 of DC rated voltage. Therefore, the minimum DC Voltage rating of the capacitors shall be 40kV.

This initial request is for a total of 28 capacitor banks, enough to build one magnet. Each bank has a total capacitance of 1400 pF +/- 5% but with a peak to peak variation in bank capacitance of +/- 1%. The capacitors will be tested for conformance to this specification.

Provided success the final request will be for a total of 8 more magnets worth of capacitor bank I.e. 8*14*2 = 224 Capacitor Bank of 1,400 pF each minimum.

The capacitor will be subject to ionizing radiation. This exposure shall not cause the devices to fail during their 100,000 hours of usage.

The capacitor will be encapsulated in silicone room temperature vulcanizing rubber as part of the magnet construction.

The desired temperature coefficient of the capacitor bank is less than +/- 2% between 25 ° C and 50 ° C, or about 800 ppm/° C in said temperature range. This can be accomplished through parallel of positive and negative temperature coefficient capacitors in each capacitor bank. The supplier shall advice on the most effective techniques. Higher temperature coefficients may be acceptable but the added cost to the completed magnet needs to be considered.

Each 1400 pF capacitor bank (however many capacitors are needed) shall be contained in a volume of approximately 3.84” x 2.5” x 3”.

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2. Electrical Requirements

2.1 Voltage and Current

- See waveforms, Figure 1 and 2
- The pulse voltage has a peak of 27 kV
- The pulse will have a rise and fall time of 200 ns with an 11 µs flattop.
- The DC voltage rating of the capacitor shall be at least 40 kV.
- The peak charging and discharging current is ~ 200 A.

2.2 Repetition Rate / Duty Cycle

- The capacitors will be operated at any repetition rate up to 1 pulse every 1.2 seconds.

2.3 Lifetime Requirement

- The expected lifetime of the capacitors is 100,000 hours, continuous duty.

2.4 Inductance

- < 50 nH for the capacitor bank

2.5 Dielectric Material

- The capacitor material shall be ceramic or mica to offer required stability and low losses typically used for pulsed applications.

2.6 Capacitive Value and Tolerances

- The average capacitance value for all capacitor banks shall be within +/-5 % of the nominal 1400 pF bank.
- The peak to peak capacitance variation from the average value within one lot of capacitor banks shall be less than +/-2% (One lot equal 28 capacitor banks)
- The difference in average capacitance bank values between lots shall be less than +/-1%.

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2.7 VOLTAGE COEFFICIENTS

- The deviation in capacitance at the rated voltage shall be no more than –5% than its capacitance at lower excitation signal.

2.8 TEMPERATURE COEFFICIENTS

- Herein temperature coefficient is defined as the temperature coefficient of the whole capacitor bank which can be made up of several parallel capacitors for a total capacitance of 1,400 pF. The temperature coefficient of each single capacitor constituting the capacitor bank can be greater, as long as its temperature drift is globally compensated (within the bank) with equal and opposite drift. E.g. Some negative and some positive temperature coefficient.
  Supplier shall advise on the most effective number of each type of capacitor to be utilized.

- Each capacitor bank shall have a positive or negative maximum temperature coefficient of 2% between 25 ° C and 45 ° C, or about 800 ppm/° C over said temperature range.

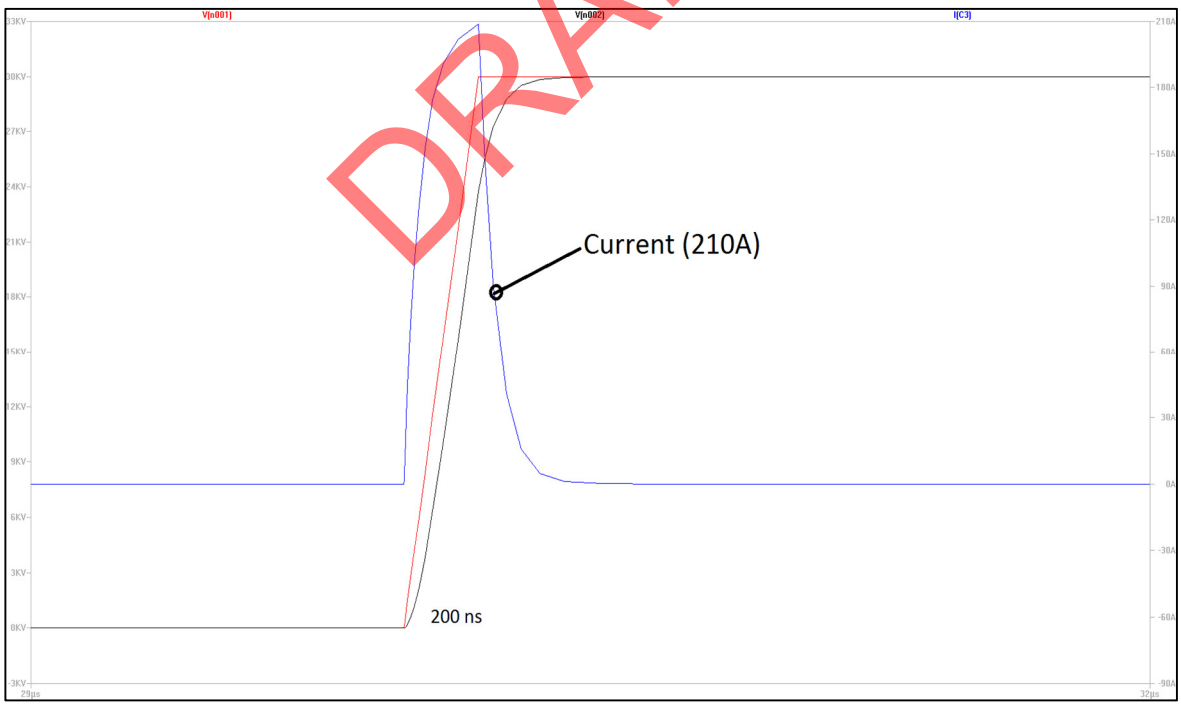

Figure 1: Charging Waveform Example

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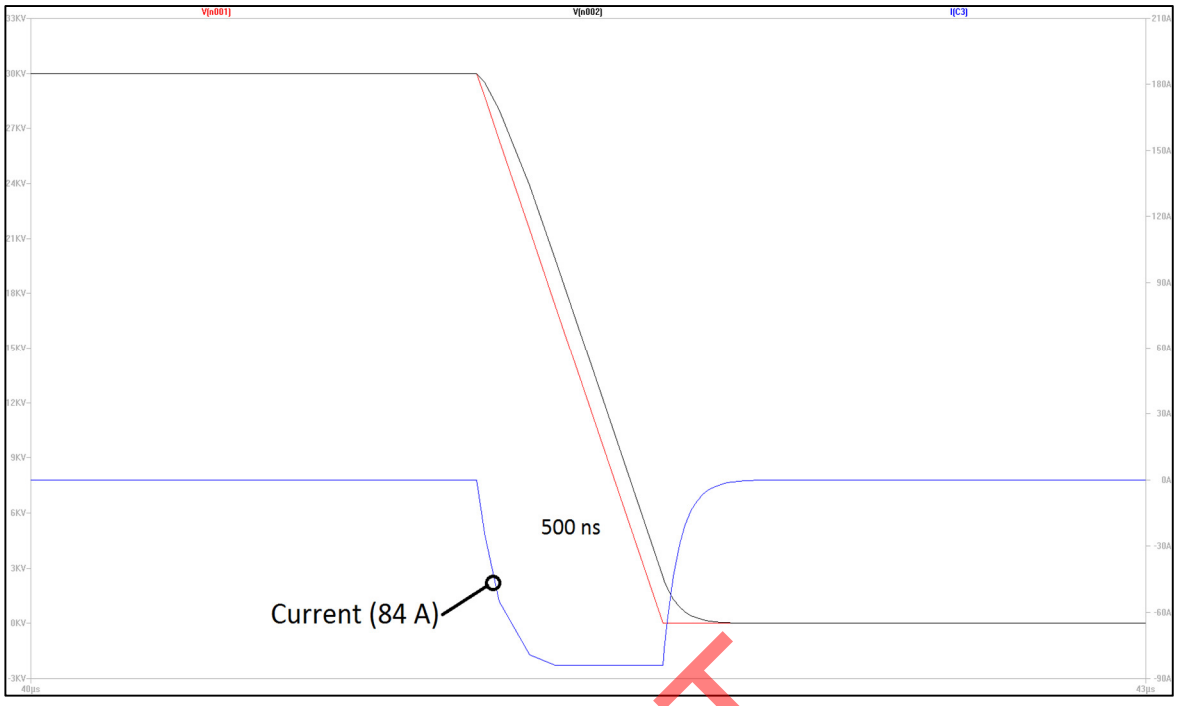

Figure 2: Discharge (11 µs after charging), waveform Example.

3. Mechanical Requirements

3.1 Case Size and Connections

- The case shall be non-metallic and have low inductance threaded connections for terminals.
- The capacitor weight must be supported by its own terminals when mounted.

3.2 Environmental Conditions

- The finished assembly containing the capacitors will be encapsulated in silicon RTV.
- The capacitor storage temperature range will be between 0° C – 50° C.

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- The capacitors operational temperature range will be between 25° C – 45° C
- The average operating temperature will be 42 C
- The capacitor will be subject to ionizing radiation of 1 MegaRad per year.
    - Materials that are known to survive this are ceramic, metal, mica and epoxy
    - Materials that may be acceptable are hard plastics with a high service temperature
    - Materials that are not acceptable are any oils or liquids or soft plastics such as PTFE

3.3 MARKING DATA

- The following minimal information shall be permanently imprinted on each capacitor:
    - Manufacturer's Name or Mark
    - Manufacturer's Model Number or Part Number
    - Nominal (working) Voltage
    - Date of Manufacture or Date Code or Serial Number

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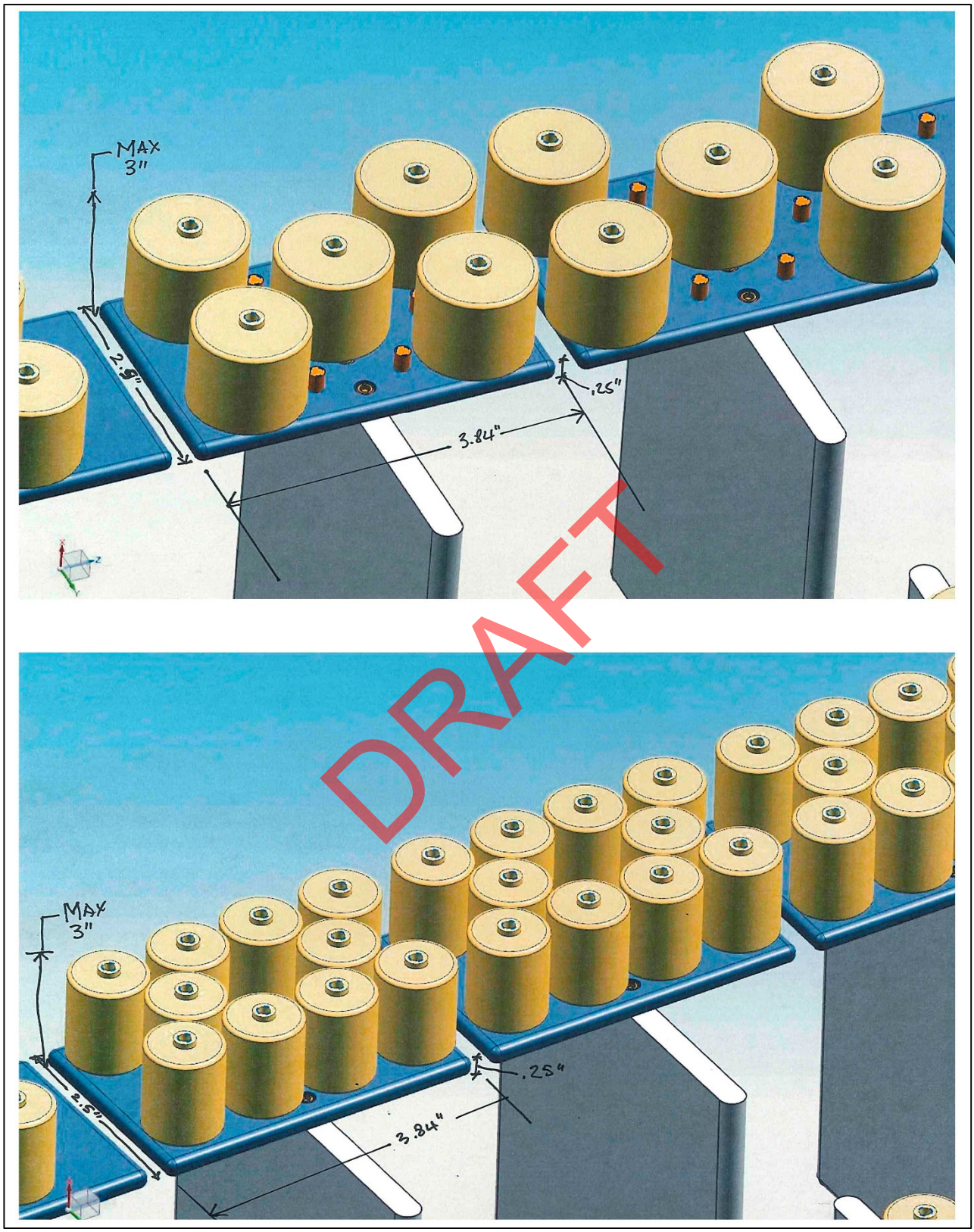

Figure 3: Cartoon Examples of the application (capacitor are in pale yellow). Size / number not determined.

4. Capacitor bank Requirement Summary

Total Units (1,400 pF per bank)	224 banks
Median Bank Capacitance (25° C)	1,400 pF
Lifetime Expectancy	100,000 hours, continuous duty
Tolerance (one lot of 28 banks)	Can be mix and matched to add up to a 1,400 pF bank. Bank: ± 28 pF (i.e. between banks); Lots ± 14 pF (i.e. within the handpicked lot).
Operating Temperature Range	25° C – 45° C
Storage Temperature	Above 0° C, less than 50° C
Minimum DC Rated Voltage	40 kV
Max Ripple Voltage	100%
Self-Resonance Frequency	> 50 MHz
Working Frequency (Operation)	200 ns rise time, 27 kV pulses. 11 µs flattop, every 1.2 seconds.
Charge Time	200 ns
Current, charge (200 ns)	210 A peak
Current, discharge (500 ns)	84 A
Time at Rated Voltage	Greater or equal to 10 µs
Discharge Time	200 ns
Discharge Current	84 A peak
Maximum Inductance	50 nH
Casing and size	Threaded connection for terminal. Needs to self-support. Bank of 1,400 pF must fit in volume: 3.84” X 2.5” X 3” max high.
Radiation Exposure	1 MegaRad per year

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