

THE PEP-II HIGH POWER BEAM DUMPING SYSTEM*

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ABSTRACT

The beam abort system utilizes a single turn beam extraction into a beam dump placed outside the rings vacuum chambers. During extraction the beam is deflected by a pulsed dipole magnet and is scanned across an exit window and the dump face to avoid overheating the materials. The system is designed for 3 A circulating beam current which corresponds to 200 kJ of stored beam energy in the High Energy Ring at 9 GeV [1].

I. INTRODUCTION

The large stored energy and the small beam size in the rings represent a very serious challenge for the machine protection system. Let's assume that the entire stored beam strikes a single spot on the protection device, such as a collimator, and that the dumping time is small enough that the deposited energy will not diffuse significantly during this time. Then a local pulsed temperature rise δT will create stresses in the collimator material.

The conservative estimate of the thermal stress in the solid material is given by $\sigma = \alpha E \delta T$, where α is the thermal expansion coefficient, and E is the modulus of elasticity. It is assumed that for reliable operation, stress σ should not exceed half of the tensile strength σ_t of the material $\sigma \leq 0.5\sigma_t$. The pulsed temperature rise δT can be determined on the basis of EGS calculations [2].

The results of such calculations for different materials and typical High Energy Ring beam size of $\sigma_{rms} = 0.35$ mm are shown in Table 1. The numbers in the table represent the stored 9 GeV beam current which can be dumped in the collimator with the stress in the material $\sigma = 0.5 \sigma_t$.

Table 1

Material	Max. beam current
<i>Beryllium</i>	<i>49 mA</i>
<i>Graphite UT-6ST</i>	<i>120 mA</i>
<i>Aluminum Al-5056</i>	<i>27 mA</i>
<i>Titanium Ti-6Al-4V</i>	<i>49 mA</i>
<i>Copper</i>	<i>1.9 mA</i>

The data in Table 1 indicates that for the typical PEP-II beam spot size ($\sigma_{rms} = 0.35$ mm) even the best material, *Graphite UT-6ST*, has a limit which is more than an order of magnitude below desirable level of 3 A stored beam.

The adequate solution of the problem will be a dedicated beam abort system which can handle a large stored beam energy in the case of critical equipment failure or a human error.

II. DESCRIPTION OF THE SYSTEM

The abort system utilizes a single turn beam extraction into a beam dump placed outside the ring vacuum chamber. During the extraction the beam scans across an exit window and the dump face to avoid overheating the materials. The High Energy Ring (HER) and Low Energy Ring (LER) systems are practically identical and designed for 3 A circulating beam current in either ring. Due to the larger stored energy, the HER system is more demanding, and, therefore, is described below.

The dump system is located in the injection straight with the extraction kicker placed downstream from the first upstream injection kicker magnet. The dump is placed upstream from the injection septum and underneath the ring vacuum chamber.

The beam extraction in the vertical direction is preferable since it takes advantage of the large horizontal beam size ($\epsilon_x \cong 25\epsilon_y$ for uncoupled beam). The phase advance between the kicker and the dump is close to 90° . The large values of the β - functions at the dump ($\beta_x=40$ m and $\beta_y=120$ m) help to minimize the extraction kicker strength [3].

The following considerations have been taken into account to determine the kicker pulse shape and geometry of the extraction region :

- The effective beam area at the exit window and the dump should be at least $A=50 \text{ mm}^2$, which permits the extraction of 200 kJ of stored beam through a Al-5056 window and the use of graphite as a dump material.

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- b. The beam should be "extractable" to the dump from any vertical orbit at the dump location between +20 mm and -20 mm relative to the center beam trajectory (bumped orbit for the beam injection plus 7 mm and central orbit minus 20 mm.)
- c. The vertical distance at the dump location between the central orbit and the vacuum chamber wall is chosen to be 35 mm, or $12 \sigma_y$ for the beam with $\mathcal{E}_y=37.5$ nm·rad. plus 5 mm orbit.
- d. The kicker operation synchronized to the ion-clearing gap should provide 100% stored beam extraction into the dump.
- e. 12 GeV operation of the HER is considered.

The geometry of the dump region is shown in Fig.1. The size of the aluminum exit window along the beam is not critical and it may be as thick as 1 cm ($\sim 0.12 X_0$). The RF taper inside the ring vacuum chamber can be made of thin (~ 1 mm) aluminum ($\sim 0.12 X_0$ along the beam for 1:10 taper.) The longitudinal space for the dump is about $20 X_0$ of graphite or 4 m.

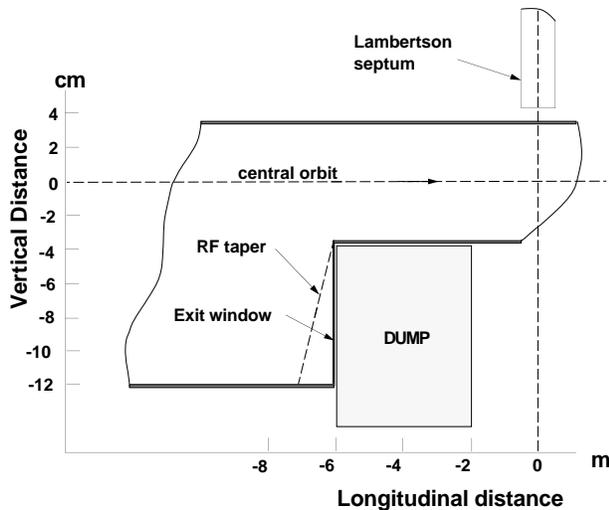


Figure 1: Geometry of the dump region.

The shape of the kicker pulse is illustrated in Fig.2. The scale at the right represents the beam vertical displacement at the exit window. The rise time of the kicker current from zero to 80% is equal to the time of the ion-clearing gap $\tau_{08}=0.37 \mu\text{sec}$. The beam is smeared vertically at the distance $\Delta Y=17$ mm, and effective area of the beam is $A=(2\pi \mathcal{E}_x \beta_x)^{1/2} \Delta Y \cong 60 \text{ mm}^2$ ($\mathcal{E}_x=50$ nm rad, $\beta_x=40$ m). The maximal deflection of 87 mm corresponds to the kicker angle $\theta_{\text{max}}=1.5$ mrad and the kicker current $I_{\text{max}}=4.7$ kA at 12 GeV.

In the case of a random kicker trigger in respect to the ion-clearing gap (or operation of the machine without an ion-clearing gap), some small number of the beam bunches

will propagate beyond the beam dump. In the worst case, when the beam is aborted from the injection bump orbit, approximately 3% of the beam bunches will continue to propagate in the vacuum chamber after the beam dump. The amplitude of the vertical betatron oscillations of those 3% or 50 bunches will vary from zero for the first bunch to $A_{\text{max}} \cong 14 \sigma_y$ ($\mathcal{E}_y=37.5$ nm·rad) for the last one. The effective transverse area of this residual beam is large enough that it will not present any danger to the integrity of the vacuum chamber. Since the aperture of the vacuum chamber is at least $10 \sigma_y$, most of the residual beam bunches (~ 36) will return to the abort kicker. The kicker magnetic field, after one beam revolution, is still strong enough ($\sim 80\%$ of B_{max}) to deflect the returning beam bunches into the dump.

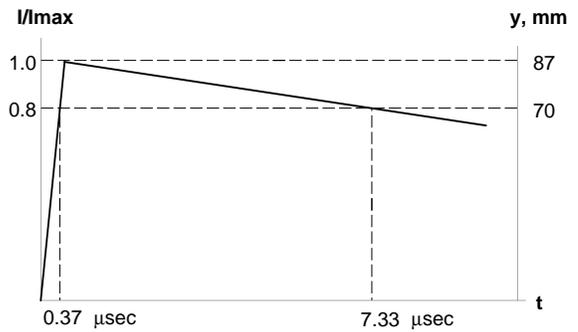


Figure 2: Shape of the kicker pulse

The kicker magnet is energized by the discharge of a storage capacitor. A free-wheeling diode connected in series with a large low voltage capacitor controls the long fall time of the current pulse.

An additional redundant kicker with associated pulser will be installed in the close proximity (next) to the first one. The trigger for the second kicker is delayed $7.33 \mu\text{sec}$ or one revolution of the beam from the first kicker. The redundant system insures safe beam disposal and prevents possible catastrophic failure of the machine if one abort kicker fails. The Beam Abort Systems in the two rings will operate independently.

References

- [1] J.T. Seeman, "PEP II Status and Plans", these proceedings.
- [2] W.R. Nelson *et al.*, "The EGS4 Code System", SLAC Report SLAC-265, Stanford, CA 94305.
- [3] M.H.R. Donald *et al.*, "Lattice Design for the High Energy Ring of the SLAC B Factory (PEP II)", these proceedings.