Kicker and Pulser Systems Required for Pbar Manipulations in the Main Ring and Tevatron

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INTRODUCTION

The six kicker systems required for proton and pbabar manipulations in the main ring and tevatron, associated with colliding beam operations, are illustrated schematically in Fig. 1. Functionally, these systems may be categorized as follows:

1. Proton targeting for pbabar production at 120-150 GeV: MR-E17-1 kicker at E17 in the main ring kicks the beam across the F17 Lambertson septum.

2. Pbar injection from the accumulator at 8 GeV: MR-E48 kicker at E48 in the main ring kicks the pbabar beam injected at F17 onto the closed orbit.

3. Proton transfer from the main ring to the tevatron at 150 GeV: MR-C48 kicker at C48 in the main ring and T-E17 kicker in the tevatron transfer through the Lambertsons at E0.

4. Pbar transfer from the main ring to the tevatron at 150 GeV: MR-E17-2 kicker at E17 in the main ring and T-D48 kicker at D48 in the tevatron transfer through the Lambertsons at E0.

5. Proton abort at 150-1000 GeV: T-B48 kicker at B48 in the tevatron kicks the proton beam across a Lambertson septum to the tevatron beam dump.

6. Pbar abort at 150-1000 GeV: T-C17 kicker at C17 in the tevatron kicks the pbabar beam into a 3 m steel dump located in the CO straight section.

In addition to these functions, systems 2, 4 (the ones involving pbabar manipulations) will need to be able to be operated in reverse with protons for commissioning. This means that system 2 will need to be able to extract 8 GeV protons from the main ring to the accumulator, and system 4 will need to transfer protons from the tevatron to the main ring at 150 GeV.

Systems 3 and 5 already exist for fixed target operations. For completeness, some of their requirements for colliding beam operations will be specified here; in general, the existing hardware can handle the requirements.
3 AND 5 BELOW, WE ASSUME A SCENARIO AS OUTLINED ABOVE, WHERE THE COLLISION POINTS WILL BE MOVED TO THE PROPER AZIMUTH SUBSEQUENT TO INJECTION.

1. (MR-E17-1). THIS SYSTEM SHOULD ALLOW SINGLE TURN EXTRACTION OF ONE BOOSTER BATCH FROM THE MAIN RING AT 120-150 GEV. HENCE A RISE TIME OF <19 USEC, WITH A FLAT TOP OF 1.6 USEC (NOT COUNTING JITTER) IS REQUIRED. THERE IS NO FALL TIME REQUIREMENT. THE REPETITION RATE IS 0.5 HZ.

2. (MR-E46) THIS SYSTEM NEEDS TO TRANSFER TYPICALLY ≤15 53 MHZ BUNCHES (4) OF PBARS FROM THE ACCUMULATOR TO THE MAIN RING. FOR THIS OPERATION, A FLAT TOP OF ~300 NSEC (NOT COUNTING JITTER) IS REQUIRED, WITH A FALL TIME OF 20 USEC. FOR COMMISSIONING WITH PROTONS, THE KICKER WILL BE USED TO EXTRACT ~15 BUNCHES WHICH HAVE BEEN TRANSFERRED FROM THE BOOSTER. THE REPETITION RATE DEPENDS UPON HOW RAPIDLY PBAR BUNCHES CAN BE PULLED FROM THE ACCUMULATOR CORE; TYPICALLY, THIS IS NOT EXPECTED TO EXCEED ONCE PER 30 SEC. FOR COMMISSIONING, A MORE RAPID REPETITION PERIOD (LIKE ONCE EVERY 10 SEC) WOULD BE CONVENIENT.

3. (MR-C46 AND T-E17) THIS SYSTEM MUST TRANSFER FROM 1 TO 6 COALESCED (*) PROTON BUNCHES FROM THE MAIN RING TO THE TEVATRON AT 150 GEV. THE COALESCED BUNCHES HAVE A DURATION OF ~12 NSEC. THE MR-C48 KICKER NEEDS A RISE TIME OF 2.0 USEC, AND A FLAT TOP OF UP TO 17.5 USEC, DEPENDING UPON HOW MANY PROTON BUNCHES ARE TO BE TRANSFERRED AT ONE SHOT. THERE IS NO FALL TIME REQUIREMENT. THE T-E17 KICKER REQUIREMENTS DEPEND UPON HOW MANY BUNCHES ARE TO BE TRANSFERRED, AND WHETHER THERE ARE ALREADY PBAR BUNCHES IN THE TEVATRON. IF THE PROTONS ARE INJECTED FIRST, THERE IS NO RISE TIME REQUIREMENT; THE DURATION (UP TO 17.5 USEC) DEPENDS UPON THE NUMBER OF BUNCHES TO BE TRANSFERRED AT ONCE, AND THE FALL TIME REQUIREMENT IS 3.5 USEC. IF THE PBARS ARE INJECTED FIRST, THE PROTONS MUST BE INJECTED ONE BUNCH AT A TIME, IN BETWEEN THE PBAR BUNCHES. THE FLAT TOP REQUIREMENT IS THEN JUST THAT OF A SINGLE PROTON BUNCH, AND THE RISE AND FALL TIMES ARE EACH 1.7 USEC. THE REPETITION PERIOD IS SOMEWHAT ARBITRARY (STRONGLY DEPENDENT ON THE SCHEME CHOSEN FOR FILLING THE COLLIDER) BUT SHOULD NEVER EXCEED THAT REQUIRED FOR FIXED TARGET OPERATION.

4. (MR-E17-2 AND T-D48) THIS SYSTEM IS VERY SIMILAR TO SYSTEM 3, EXCEPT FOR THE FOLLOWING: (A) THE TRANSFER OF PBARS IS NEVER EXPECTED TO INVOLVE MORE THAN A SINGLE COALESCED (*) 53 MHZ BUNCH IN THE MAIN RING AT A TIME. CONSEQUENTLY, THE FLAT TOP REQUIREMENT IS JUST THE LENGTH OF A COALESCED BUNCH (NOT COUNTING TIMING JITTER). (B) THE SYSTEM MUST BE ABLE TO BE COMMISSIONED AND TESTED WITH SINGLE BUNCH PROTON TRANSFER FROM THE TEVATRON TO THE MAIN
THE KICKER AND PULSER REGULATION REQUIREMENTS HAVE BEEN
SEPARATED INTO A FLAT-TOP UNIFORMITY REQUIREMENT, AND A
PULSE-TO-PULSE REGULATION REQUIREMENT. IN GENERAL, THE
FORMER REQUIREMENT RESULTS FROM CRITERIA ON BETATRON
PHASE-SPACE DILUTION, WHEREAS THE LATTER RESULTS FROM
CRITERIA ON REPEATABILITY OF BEAM POSITION AT SOME CRITICAL
EXTRACTION/INJECTION APERTURE, OR AT THE PBAR PRODUCTION
TARGET. THE SPECIFIC CRITERIA AND THE ResultING
REQUIREMENTS ARE LISTED IN TABLE 2. THE BETATRON
PHASE-SPACE DILUTION LIMIT FOR EXTRACTED PROTONS HAS BEEN
(SOMETHING ARBITRARILY) SET AT 10%, AND THAT FOR INJECTED AND
TRANSFERRED PBARS AT 1%. THE TARGETING OR
EXTRACTION/INJECTION POSITION REPEATABILITY HAS BEEN SET AT
10% OF THE BEAM SIZE. THESE NUMBERS SHOULD BE VIEWED AS
TENTATIVE GUIDELINES FOR THE KICKER ELECTRICAL DESIGN. THE
FLAT-TOP SLOPE REQUIREMENT ON THE T-C17 KICKER IS REALLY A
SPECIFICATION, NOT A LIMIT, TO ALLOW FOR THE POSSIBILITY OF
Sweeping OF THE PBAR SPOT ACROSS THE PBAR DUMP DURING ABOvT.

Generally, the allowable upper limit for kicker current
after the end of the fall time is just the percentage
specified as the flat-top uniformity requirement.

The flat-top specifications for System 4 are quite
strict. If these are not able to be approached in a
realistic design (especially in the case of T-D40), some of
the resulting injection oscillations may be able to be
reduced, before phase-space dilution occurs, using the
planned active tevatron damper system (5). This system is
expected to be able to damp up to ±1 mm injection errors,
with only a 10% increase in betatron phase space. We note
in Table 2 the relaxed flat-top requirements necessary to
limit the dilution to 10%, assuming the use of this damper
(in "power boost" 4 KV mode). The kicker design should aim
at the number specified for no damper, but must be sure to
come within the specification noted for use with the damper.

TENTATIVE KICKER AND PULSER DESIGNS

TENTATIVE DESIGNS HAVE BEEN SUGGESTED FOR EACH OF THE
REQUIRED NEW KICKER SYSTEMS. THE ATTEMPT HAS BEEN MADE,
WHEREVER POSSIBLE, TO UTILIZE EXISTING KICKER DESIGNS. A
SUMMARY OF THE TENTATIVE DESIGN PARAMETERS IS PRESENTED IN
TABLE 3; EACH DESIGN IS DISCUSSED BRIEFLY BELOW.

1. (MR-E17-1) The requirements for this system are
essentially the same as for an abort from the main ring;
thus the kicker can be very similar to the main ring abort
kicker, except that the rise time and flat top requirements
are considerably relaxed. Some of the parameters for a
design utilizing a 1.9 m main ring abort kicker magnet are
shown in Table 3.
REFERENCES


2. D. Boussard, Private Communication


4. J. Maclachlan, PBar Note 350 (10/17/83)

5. C. Moore, R. Rice, "Tevatron Damper System"
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>KICKER</th>
<th>MINIMUM RISE TIME (USEC)</th>
<th>MINIMUM FALL TIME (USEC)</th>
<th>BEAM PULSE DURATION (USEC)</th>
<th>KICKER TIMING JITTER (USEC)</th>
<th>CONTROL TIMING JITTER (USEC)</th>
<th>MINIMUM FLAT TOP (USEC)</th>
<th>FLAT TOP ANGLE (DEGREES)</th>
<th>FLAT TOP ANGLE OUT (DEGREES)</th>
<th>FLAT TOP ANGLE (GEV)</th>
<th>FLAT TOP ANGLE (T-n)</th>
<th>MINIMUM REPEAT PERIOD (SEC)</th>
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<tbody>
<tr>
<td>1</td>
<td>MR-E17-1</td>
<td>19</td>
<td>--</td>
<td>1.6</td>
<td>±0.2</td>
<td>±0.5</td>
<td>1.8</td>
<td>-750</td>
<td>150</td>
<td>0.375</td>
<td>2</td>
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<tr>
<td>2</td>
<td>MR-E48</td>
<td>20</td>
<td>20</td>
<td>0.3</td>
<td>±0.5</td>
<td>±0.5</td>
<td>0.5</td>
<td>+800</td>
<td>8</td>
<td>0.021</td>
<td>10</td>
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<tr>
<td>3*</td>
<td>MR-C48</td>
<td>20</td>
<td>--</td>
<td>.01 (3)†</td>
<td>±0.2</td>
<td>±0.2</td>
<td>.09 (3)</td>
<td>17.5</td>
<td>--</td>
<td>--</td>
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<tr>
<td></td>
<td>T-E17</td>
<td>1.7</td>
<td>1.7</td>
<td>.01 (3)†</td>
<td>±0.2</td>
<td>±0.2</td>
<td>.09 (3)</td>
<td>17.5</td>
<td>--</td>
<td>--</td>
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<tr>
<td>4</td>
<td>MR-E17-2</td>
<td>20</td>
<td>20</td>
<td>.01 (3)†</td>
<td>±0.2</td>
<td>±0.2</td>
<td>.09 (3)</td>
<td>17.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td></td>
<td>T-D48</td>
<td>1.7 (1.5)†</td>
<td>1.7 (1.5)†</td>
<td>.01 (3)†</td>
<td>±0.2</td>
<td>±0.2</td>
<td>.09 (3)</td>
<td>17.5</td>
<td>--</td>
<td>--</td>
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<td>5*</td>
<td>T-B48</td>
<td>1.6</td>
<td>--</td>
<td>2.1</td>
<td>±0.2</td>
<td>±0.2</td>
<td>2.1</td>
<td>150</td>
<td>150</td>
<td>1.375</td>
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<td>6</td>
<td>T-C17</td>
<td>2.1</td>
<td>--</td>
<td>2.1</td>
<td>±0.2</td>
<td>±0.2</td>
<td>2.1</td>
<td>150</td>
<td>150</td>
<td>1.5</td>
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</tr>
<tr>
<td></td>
<td>FIT MAG. PULSER</td>
<td>--</td>
<td>--</td>
<td>1.6</td>
<td>±0.5</td>
<td>±0.5</td>
<td>1.8</td>
<td>--</td>
<td>--</td>
<td>--</td>
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*— ALREADY EXISTING SYSTEM
†— FOR BUNCH COALESCEENCE IN THE TEVATRON
<table>
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<tr>
<th>KICKER or PULSER</th>
<th>FLAT-TOP UNIFORMITY CRITERION</th>
<th>FLAT-TOP REQUIREMENT ON SQ/8</th>
<th>PULS-TO-PULSE REG. CRITERION</th>
<th>PULS-TO-PULSE REQUIREMENT ON SQ/8</th>
<th>FLAT TOP DURATION (US)</th>
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<tr>
<td><strong>FIT MAG. PULSER</strong></td>
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<td>FIT MAG. PULSER</td>
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<tr>
<td>1. MR-ET7-1</td>
<td>extracted proton $\frac{S_x}{\delta y} &lt; 10%$</td>
<td>$&lt; 3 \times 10^{-4}$</td>
<td>$(\frac{S_x}{\delta y})_{max} &lt; 10%$</td>
<td>$&lt; 2 \times 10^{-4}$</td>
<td>1.8</td>
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<td>injected $\frac{S_x}{\delta y} &lt; 10%$</td>
<td>$&lt; 9 \times 10^{-5}$</td>
<td>$(\frac{S_x}{\delta y})_{max} &lt; 10%$</td>
<td>$&lt; 3 \times 10^{-3}$</td>
<td>0.5</td>
</tr>
<tr>
<td>2. MR-ET7-2</td>
<td>extracted $\bar{P}$ $\left(\frac{S_x}{\delta x}\right) &lt; 10%$</td>
<td>$&lt; 0.09%$</td>
<td>$(\bar{P})_{max} &lt; 10%$</td>
<td>$&lt; 0.8%$</td>
<td>0.09 (38)$^{+}$</td>
</tr>
<tr>
<td></td>
<td>$\left(\frac{S_x}{\delta x}\right) &lt; 10%$</td>
<td>$&lt; 2%$</td>
<td>$(\bar{P})_{max} &lt; 10%$</td>
<td>$&lt; 0.6%$</td>
<td>0.09 (38)$^{+}$</td>
</tr>
<tr>
<td>3. T-C17</td>
<td>$\delta_x &lt; 2.5\text{mm}$</td>
<td>$&lt; 8%$</td>
<td>$(\frac{S_x}{\delta x})_{dum} &lt; 10%$</td>
<td>$&lt; 0.6%$</td>
<td>21</td>
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$^{+}$-- FOR BUNCH COALESCENCE IN THE TEVATRON

$^{*}$-- ASSUMING THE USE OF TEVATRON DAMPER SYSTEM
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>KICKER</th>
<th>DESIGN PARAMETERS</th>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
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<td>KICKER</td>
<td>MAGNET STYLE</td>
<td>GAP</td>
</tr>
<tr>
<td>1</td>
<td>MR-E17-1, MR-ABORT</td>
<td>MODULE</td>
<td>2&quot; x 4(\frac{3}{4})</td>
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<td>2</td>
<td>MR-E48</td>
<td>CH8-TYPE MODULE</td>
<td>2(\frac{1}{8}) x 5</td>
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<td>4</td>
<td>MR-E17-2, MR-ABORT</td>
<td>MODULE</td>
<td>2&quot; x 4(\frac{3}{4})</td>
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<tr>
<td>T-048</td>
<td>T-E17 MAGNET</td>
<td>(MODIFIED)</td>
<td>2(\frac{1}{4}) x 3(\frac{3}{4})</td>
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<tr>
<td>6</td>
<td>T-C17</td>
<td>MR-ABORT MODULE</td>
<td>2&quot; x 4(\frac{3}{4})</td>
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