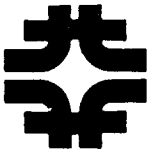

Fermilab

$\bar{p}$ Note #365

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

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2/84

KICKER AND PULSER SYSTEMS REQUIRED FOR PBAR MANIPULATIONS IN THE MAIN RING AND TEVATRON

INTRODUCTION

THE SIX KICKER SYSTEMS REQUIRED FOR PROTON AND PBAR 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 PBAR 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 PBAR 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 PBAR BEAM INTO A 3 M STEEL DUMP LOCATED IN THE C0 STRAIGHT SECTION.

IN ADDITION TO THESE FUNCTIONS, SYSTEMS 2 ,AND 4 (THE ONES INVOLVING PBAR 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 COLLISON 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-E48) 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 $\sim$ 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-C48 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 $\sim$ 12 NSEC. THE MR-C48 KICKER NEEDS A RISE TIME OF 20 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 UNIFORMIITY 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 (SOMEWHAT 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 ABORT.

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-D48), 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.

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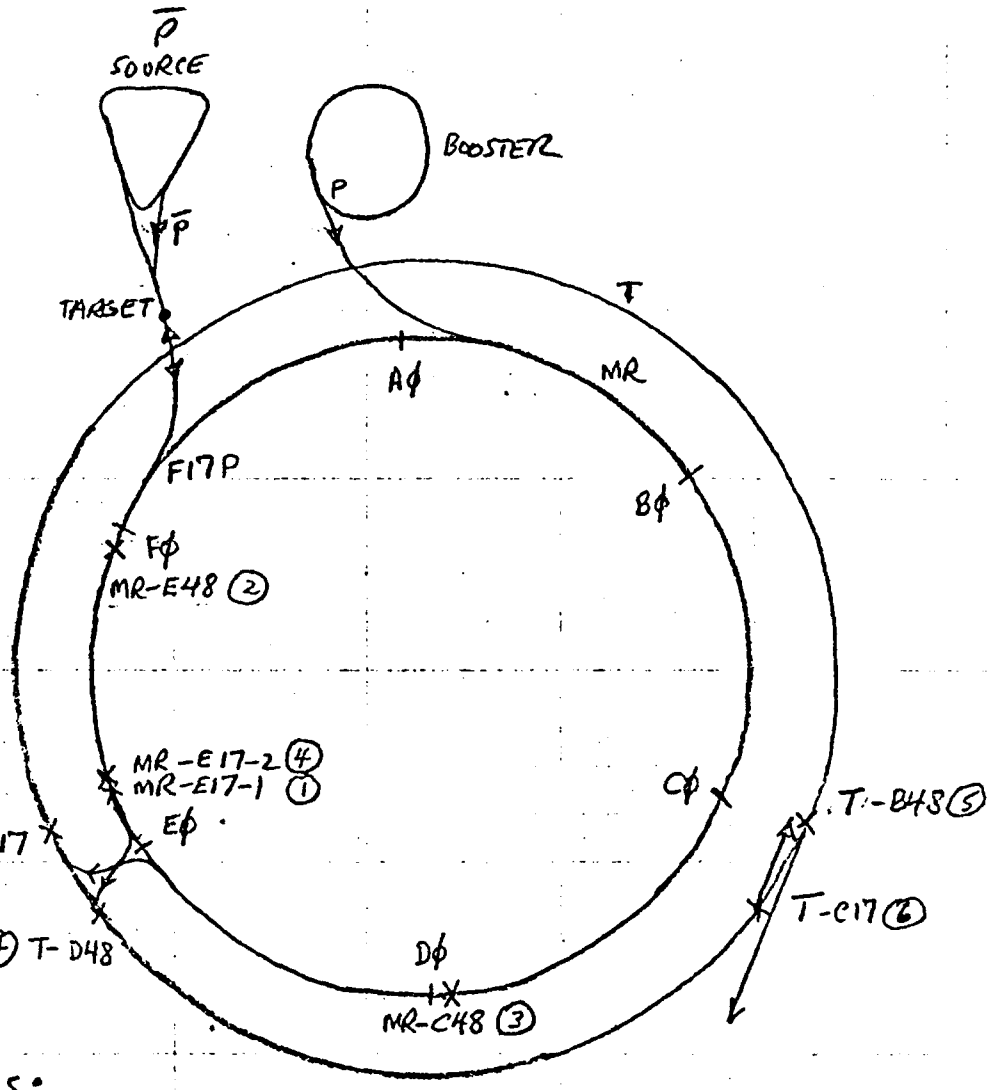
FIG. 1



KICKER SYSTEMS:

PULSER: F17P

1)	p EXTRACTION AT F17	MR-E17-1
2)	$\bar{p}$ INJECTION AT F17	MR-E48
3)	p TRANSFER AT Eϕ	{MR-C48, T-E17} (EXISTS)
4)	$\bar{p}$ TRANSFER AT Eϕ	{MR-E17-2, T-D48}
5)	p ABORT	T-B48 (EXISTS)
6)	$\bar{p}$ ABORT	T-C17

TABLE 1

F17 PULSER + KICKER TIMING AND STRENGTH REQUIREMENTS

SYSTEM	KICKER	MINIMUM RISETIME (μsec)	MINIMUM FALL TIME (μsec)	BEAM PULSE DURATION (μsec)	KICKER TIME JITTER (μsec)	CONTROL TIMING JITTER (μsec)	MINIMUM FLAT TOP (μsec)	KICK ANGLE (+ ⇒ radial out) (μrad)	E (GeV)	Bℓ (T-m)	MINIMUM REPITITION PERIOD (SEC)
1	MR-E17-1	19.	—	1.6	±.02	±.05	1.8	-750	150	.375	2
2	MR-E48	20.	20.	0.3	±.05	±.05	0.5	+800	8	.021	10
3*	MR-C48	20	—	.01 (.3)†	±.02	±.02	.09(.38) – 17.5	—	—	—	—
	T-E17	1.7	1.7	.01 (.3)†	±.02	±.02	.09(.38)† – 17.5				
4	MR-E17-2	20	20	.01 (.3)†	±.02	±.02	.09(.38)	+750	150	.375	30
	T-D48	1.7 (1.5)†	1.7 (1.5)†	.01 (.3)†	±.02	±.02	.09(.38)†	-1000	150	.50	
5*	T-B48	1.6	—	21	±.02	±.02	21.1	—	—	—	—
6	T-C17	2.1	—	21	±.02	±.02	21.1	+450	1000	1.5	30
	F17 MAG. PULSER	—	—	1.6	±.05	±.05	1.8				2

* — ALREADY EXISTING SYSTEM

† — FOR BUNCH COALESCENCE IN THE TEVATRON

TABLE 2: FIT PULSER AND KICKER REGULATION REQ'S

FERMILAB ENGINEERING NOTE

SUBJECT | NAME | DATE | REVISION DATE | SERIAL-CATEGORY | PROJECT | SECTION | PAGE

KICKER OR PULSER	FLAT-TOP UNIFORMITY CRITERION	FLAT-TOP REQUIREMENT ON SO/O	PULSE-TO-PULSE REG. CRITERION	PULSE-TO-PULSE REQUIREMENT ON SO/O	FLAT TOP DURATION (MSEC)
FIT MAG PULSER	extracted proton $\frac{\delta y'}{\sigma_{y'}} < 10\%$	$< 3\times10^{-4}$	$\left(\frac{\delta y}{\sigma_y}\right)^{P}_{targ} < 10\%$	$< 2\times10^{-4}$	1.8
	injected $\bar{P}$ $\frac{\delta y'}{\sigma_{y'}} < 1\%$	$< 9\times10^{-5}$	$\left(\frac{\delta y}{\sigma_y}\right)^{\bar{P}}_{LAMB} < 10\%$	$< 3\times10^{-3}$	0.5
1. MR-ET7-1	extracted proton $\left(\frac{\delta x'}{\sigma_{x'}}\right) < 10\%$	$< .7\%$	$\left(\frac{\delta x}{\sigma_x}\right)^{P}_{targ} < 6\%$	$< 1.3\%$	1.8
2. MR-E48	injected $\bar{P}$ $\left(\delta x'/\sigma_{x'}\right) < 1\%$	$< .35\%$*	$\left(\frac{\delta x}{\sigma_x}\right)^{\bar{P}}_{LAMB} < 10\%$	$< 1.3\%$	0.5
4. MR-ET7-2	extracted $\bar{P}$ $\left(\delta x'/\sigma_{x'}\right) < 1\%$ $< 10\%$	$< .09\%$ $< 2\%$*	$\left(\frac{\delta x}{\sigma_x}\right)^{\bar{P}}_{LAMB} < 10\%$	$< .8\%$	.09 (.38)†
T-D48	injected $\bar{P}$ $\left(\delta x'/\sigma_{x'}\right) < 1\%$ $< 10\%$	$< .06\%$ $< 1.7\%$*	$\left(\frac{\delta x}{\sigma_x}\right)^{\bar{P}}_{LAMB} < 10\%$	$< .6\%$	.09 (.38)†
6. T-C17	δx AT $\bar{P}$ DUMP ~ 2.5 mm	$\sim 8\%$	$\left(\frac{\delta x}{\sigma_x}\right)_{DUMP} < 10\%$	$< .6\%$	21

† – FOR BUNCH COALESCENCE IN THE TEVATRON

* – ASSUMING THE USE OF TEVATRON DAMPER SYSTEM

KICKER TENTATIVE DESIGN PARAMETERS

TABLE 3

SYSTEM	KICKER	MAGNET STYLE	GAP (in)	APERTURE (in)	ℓ (m)	B (T)	I (kA)	L (μH)	PULSER STYLE	V (kV)	RISE TIME (μSec)	FLAT TOP (μSec)	FALL TIME (μSec)
1	MR-E17-1	MR ABORT MODULE	$2 \times 4\frac{3}{4}$	$1\frac{1}{2} \times 3\frac{1}{2}$	1.9	.197	8	5.9	MR-ABORT: (MODIFIED)	47	>1.5	>2	—
2	MR-E48	C48-TYPE MODULE	$2\frac{1}{8} \times 5$	$1\frac{1}{2} \times 3\frac{1}{2}$	1	.021	.85	3.6	SCR SWITCHED RESONANT LC	.6	15.7	1.4	15.7
4	MR-E17-2	MR ABORT MODULE	$2 \times 4\frac{3}{4}$	$1\frac{1}{2} \times 3\frac{1}{2}$	1.9	.197	8	5.9	MR-ABORT: (MODIFIED)	47	71.5	>.14	<20
	T-048	T-E17 MAGNET (MODIFIED) OR SIMILAR	$2\frac{1}{4} \times 3\frac{1}{2}$	$1\frac{5}{8} \times 3\frac{3}{8}$	2 x 2.1	.125	5	8.1	CABLE PFN $Z_0 = 3.125\ \Omega$ (TYPICAL)	62	.9	.08 (.38)	.9
6	T-C17	MR ABORT MODULE	$2 \times 4\frac{3}{4}$	$1\frac{1}{2} \times 3\frac{1}{2}$	3x 1.9	.26	10.5	5.9	MR ABORT: STANDARD	62	1.5	>20	—