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External beam line ramped magnets

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I. Introduction

During the slow extracted (SEB) mode of operation of the AGS, 0.5 to 1.0 percent of momentum spread or variation is intentionally put on the beam just prior to extraction. It is accomplished by operating the AGS rf system in a phase-back (unstable phase angle) mode for a short period of time (i.e., a few milliseconds). In the process of resonant extraction, the particles that have a higher momentum are inherently extracted first, while those with the lowest momentum come out last. The extracted beam as it proceeds in the SEB switchyard and the various lines, therefore, undergoes a variation in position whenever it passes through a bending magnet. Since the SEB lasts for approximately 1 second, a beam spot, after passing through a constant magnetic field, will sweep an amount equivalent to the 0.5 percent momentum variation per 1 second. The variation is fairly linear with spill time. So if we could make the large bending field to vary an equivalent small amount but in the opposite direction, the beam spot would stay fixed downstream of that bend. Subsequent bends later on will bring the motion back and hence also will have to be ramped.

II. How Accomplished

What is ultimately desired in transporting the SEB is to keep the beam steady on a target so that the maximum secondary beam production is guaranteed. In addition, if one could reduce or eliminate beam sweeping in the middle of the beam lines, this would reduce the need for large vacuum apertures and also the possibility of beam loss. The method that is used in the AGS to stabilize the motion of the SEB is to ramp several selected bending magnets (dipoles) in the line. The dipoles have a nominal dc current in their coils which is increased or decreased during the time beam is passing through them.

Technically, a function generator (FG) signal is summed into the current reference input of the particular power supply which drives the appropriate dipole. The external beam FG's are started at T_0 and stopped at T_{INVERT}. They run at a clock input rate of 100 Hertz (10 milliseconds). The functions are generated by the PDP-10 AGS computer and are stored locally in the memory of the FG card. A function is generated or modified by entering the desired breakpoint information (which consist of TIME, AMPLITUDE and SLOPE settings) into the AGAST program. A facility program named FUNK handles the entered settings and affects the proper FG function. (See Computerized Accelerator Operating System (CAOS) Software Note: FUNK-A, latest revision).

The ramp files currently in operation are found in the SEB AREA of AGAST under their proper ramp designation headings. Figure 1 gives the current list of these names together with their associated beam lines and beam line magnet designation. Figures 2a,b show the settings of the ramp parameters during a particular SEB run in the winter FY 1987 running period. Figures 3a,b show some of the FG waveforms during this same period.

In setting up functions, one must remember that the generated voltage program feeds the current reference input of a slow-acting, well-regulated dc power supply. Also that most of the magnets that are being ramped are solid core type and have long eddy current effects. Studies[1] have shown that small current (field) changes seem to work well. However, the delay in the field (due to the magnet time constant and the eddy current) in the magnet gap must be taken into account. This means that the current function is started usually much before the actual beam time (see Fig. 3a, b).

Due to some of the problems of the previous paragraphs, a variation of a combination dc and ac magnet is implemented in the magnet designated DD89. Two magnets (DD8 and DD9) are located at approximately the midpoint of the big bend (~21°) that transports the beam to the D-target. A DD89T trim magnet and power supply was designed for ramping and for beam position servo type control. The scheme consists of laminated magnets together with their excitation coils that are inserted in the gap of the solid core main magnets. The laminated magnet inserts provide the low reluctance path for the ac flux. The power supply (P.S. No. 32-4) is also a transistor regulator type with higher frequency response and therefore follows the ramping programs more closely. It powers the two inserts in series.

II. Function Generator Description

A. Hardware

The function generator physically consists of a single datacon standard printed circuit board on which all the communication, memory and D/A components are mounted. The generator is described in CAOS hardware Note D2FGEN-A. The schematic diagram number is D09-E1234-5A.

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[1] Field Ramping in Solid Core Bending Magnets, EP&S Division Technical Note No. 36, September 23, 1970.

To implement a datacon function generator one requires a standard datacon crate which has a crate controller, ± 15 volt and + 5 volt power supplies, and an empty slot which one wires for a function generator. The two datacon connectors are used to wire the necessary address lines, data lines, control lines, clock, R/S, etc. The card requires two datacon addresses, one for control and one for data entry. Figure 4 shows a typical wiring sequence for a datacon function generator (in this case C1RMP) For a typical function generator bucket wiring see schematic drawing No. D09-E832-3B.

B. Software

1. Operational Program

As mentioned earlier, the dcn function generator operational control is handled via the AGAST/FUNK programs in the AGS PDP10 computer (see CAOS Software Tech. Note: FUNK-A). The programming or function set-up follows the breakpoint format, i.e. at each specified time an amplitude and a slope are set. These settings apply until the next breakpoint time is turned on. Normally, up to eight breakpoints are presently handled.

2. Test Programs

Two test programs also exist which exercise the data transmission and memory of the function generator card. These are called FGTEST and NFGT.

The FGTEST program uses the FG cards' internal clock and exercises all the FG memory locations and D/A function. Therefore if any glitches (dropped bits, etc.) occur, this program will pick them up. The program also reads back the data and will give messages in case of any errors.

The NFGT program by-passes the FUNK program but simulates many of its functions. It is therefore used if one suspects that the FUNK program is not controlling the FG properly. The test program utilizes the external clock and is used by specifying the devices' two addresses and the desired TIME, AMPLITUDE and SLOPE commands and their corresponding values.

These two test program are not presently documented by a technical note but hopefully will be in the near future. However, individuals in the Department who are familiar with them can be contacted if one desires to run these programs.

RAMP NAME	MAGNET(S)		
A2 RMP	AD2 & 3	}	SWY A LINE
A5 RMP	AD5-8	}	
B4 RMP	BD4	}	SWY B LINE
B5 RMP	BD5-8	}	
C1 RMP	CD1	}	SWY C LINE
C2 RMP	CD2 & 3	}	
D7 RMP	DD89T (DD7;DD8&9)	}	SWY D LINE
DE RMP	DD14	}	
CP RMP	C3P1	}	SEC BM LINES
(B1 RMP)	B1D181	}	

Fig. 1. External beam function generators.

Note: 1. This list does not include the primary target beam position servo magnets which could and sometimes are also ramped. These are described in a separate Tech. Note.

2. CPRMP function is presently being switched between C3P1 and B1D181 magnets.

3. All of the Fig. 1 FG's are physically located at TBH East.

SEB A2RMP 27-Feb-87 09:49 23.3
TIME= 2200 PRIORITY= 3

	AREA	EQPT	REQUEST	READBACK
1	SEB	AD2&3	3233A ON	3130A 103
2	SEB	A21A	2000	10MS TZERO
3	SEB	A21T	60 ON	10MS TZERO
4	SEB	A21S	5 RMP	10MS TZERO
5	SEB	A22A	2000	10MS TZERO
6	SEB	A22T	180 ON	10MS TZERO
7	SEB	A22S	6 LIN	10MS TZERO
8	SEB	A23A	0	10MS TZERO
9	SEB	A23T	220 OFF	10MS TZERO
10	SEB	A23S	500 LIN	10MS TZERO
11	SEB	A24A	0	10MS TZERO
12	SEB	A24T	220 ON	10MS TZERO
13	SEB	A24S	2000 LIN	10MS TZERO

SEB A5RMP 27-Feb-87 09:49 37.3
TIME= 2200 PRIORITY= 3

	AREA	EQPT	REQUEST	READBACK
1	SEB	AD5-8	2749A ON	2653A 96
2	SEB	A51A	-900	10MS TZERO
3	SEB	A51T	30 ON	10MS TZERO
4	SEB	A51S	10 LIN	10MS TZERO
5	SEB	A52A	-1140	10MS TZERO
6	SEB	A52T	100 ON	10MS TZERO
7	SEB	A52S	9 RMP	10MS TZERO
8	SEB	A53A	-900	10MS TZERO
9	SEB	A53T	10 OFF	10MS TZERO
10	SEB	A53S	2 LIN	10MS TZERO
11	SEB	A54A	0	10MS TZERO
12	SEB	A54T	270 ON	10MS TZERO
13	SEB	A54S	1007 LIN	10MS TZERO

SEB B4RMP 27-Feb-87 09:49 51.4
TIME= 2200 PRIORITY= 3

	AREA	EQPT	REQUEST	READBACK
1	SEB	BD4	2340A ON	2412A -72
2	SEB	B41A	-1800	10MS TZERO
3	SEB	B41T	50 ON	10MS TZERO
4	SEB	B41S	0 RMP	10MS TZERO
5	SEB	B42A	0	10MS TZERO
6	SEB	B42T	230 OFF	10MS TZERO
7	SEB	B42S	100 LIN	10MS TZERO
8	SEB	B43A	1500	10MS TZERO
9	SEB	B43T	0 OFF	10MS TZERO
10	SEB	B43S	0 LIN	10MS TZERO
11	SEB	B44A	0	10MS TZERO
12	SEB	B44T	250 ON	10MS TZERO
13	SEB	B44S	2000 LIN	10MS TZERO

SEB B5RMP 27-Feb-87 09:50 02.6
TIME= 2200 PRIORITY= 3

	AREA	EQPT	REQUEST	READBACK
1	SEB	BD5-8	3082A ON	3055A 27
2	SEB	B51A	-20	10MS TZERO
3	SEB	B51T	36 ON	10MS TZERO
4	SEB	B51S	101 LIN	10MS TZERO
5	SEB	B52A	-325	10MS TZERO
6	SEB	B52T	50 ON	10MS TZERO
7	SEB	B52S	16 RMP	10MS TZERO
8	SEB	B53A	500	10MS TZERO
9	SEB	B53T	200 ON	10MS TZERO
10	SEB	B53S	6 LIN	10MS TZERO
11	SEB	B54A	0	10MS TZERO
12	SEB	B54T	241 ON	10MS TZERO
13	SEB	B54S	510 LIN	10MS TZERO

SEB C1RMP 27-Feb-87 09:50 13.9
TIME= 1000 PRIORITY= 4

	AREA	EQPT	REQUEST	READBACK
1	SEB	CD1	2225A ON	2240A -15
2	SEB	C11A	175	10MS TZERO
3	SEB	C11T	90 ON	10MS TZERO
4	SEB	C11S	500 LIN	10MS TZERO
5	SEB	C12A	-400	10MS TZERO
6	SEB	C12T	110 OFF	10MS TZERO
7	SEB	C12S	0 LIN	10MS TZERO
8	SEB	C13A	2000	10MS TZERO
9	SEB	C13T	2000 LIN	10MS TZERO
10	SEB	C13S	800 LIN	10MS TZERO
11	SEB	C14A	2000 LIN	10MS TZERO
12	SEB	C14T	750 OFF	10MS TZERO
13	SEB	C14S	100	10MS TZERO

SEB C2RMP 27-Feb-87 09:50 22.1
TIME= 2200 PRIORITY= 3

	AREA	EQPT	REQUEST	READBACK
1	SEB	CD2&3	3279B ON	3274B 5
2	SEB	C21A	2000 LIN	10MS TZERO
3	SEB	C21T	750 OFF	10MS TZERO
4	SEB	C21S	2000 LIN	10MS TZERO
5	SEB	C22A	60 ON	10MS TZERO
6	SEB	C22T	2000 LIN	10MS TZERO
7	SEB	C22S	1496	10MS TZERO
8	SEB	C23A	60 ON	10MS TZERO
9	SEB	C23T	1007 LIN	10MS TZERO
10	SEB	C23S	3 LIN	10MS TZERO
11	SEB	C24A	20 OFF	10MS TZERO
12	SEB	C24T	-1500	10MS TZERO
13	SEB	C24S	0	10MS TZERO

Figure 2a

SEB D7RMP 27-Feb-87 09:50 44.9
TIME= 1000 PRIORITY= 4

	AREA	EQPT	REQUEST	READBACK
1	SEB	DD7	2470A ON	2493A -23
2	SEB	DD8&9	3675A ON	3238A 437
3	SEB	DD89T	2000A STBY	6A
4	SEB	D8POS	2000	16 1984
5	SEB	D8GN	1 LOW	9 -8
6	SEB	D71A	1000	10MS TZERO
7	SEB	D71T	63 ON	10MS TZERO
8	SEB	D71S	1000 LIN	10MS TZERO
9	SEB	D72A	2000	10MS TZERO
10	SEB	D72T	70 ON	10MS TZERO
11	SEB	D72S	9 LIN	10MS TZERO
12	SEB	D73A	0	10MS TZERO
13	SEB	D73T	240 OFF	10MS TZERO
14	SEB	D73S	1000 LIN	10MS TZERO
15	SEB	D74A	0	10MS TZERO
16	SEB	D74T	220 ON	10MS TZERO
17	SEB	D74S	2000 LIN	10MS TZERO

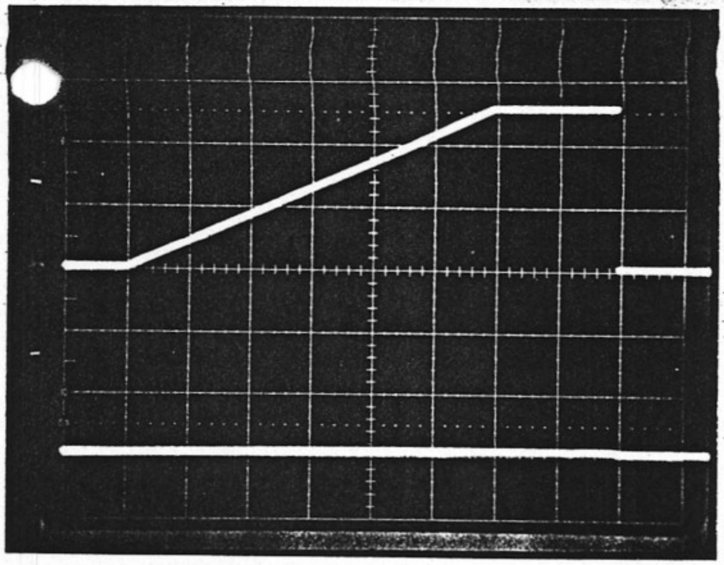
SEB DERMP 27-Feb-87 09:50 50.7
TIME= 1000 PRIORITY= 4

	AREA	EQPT	REQUEST	READBACK
1	SEB	DD14	1370A ON	1360A 10
2	SEB	DE1A	-300	10MS TZERO
3	SEB	DE1T	45 ON	10MS TZERO
4	SEB	DE1S	10 RMP	10MS TZERO
5	SEB	DE2A	70	10MS TZERO
6	SEB	DE2T	90 OFF	10MS TZERO
7	SEB	DE2S	2 RMP	10MS TZERO
8	SEB	DE3A	-750	10MS TZERO
9	SEB	DE3T	150 ON	10MS TZERO
10	SEB	DE3S	20 RMP	10MS TZERO
11	SEB	DE4A	0	10MS TZERO
12	SEB	DE4T	220 ON	10MS TZERO
13	SEB	DE4S	100 LIN	10MS TZERO

SEB CPRMP 27-Feb-87 09:50 36.3
TIME= 2200 PRIORITY= 3

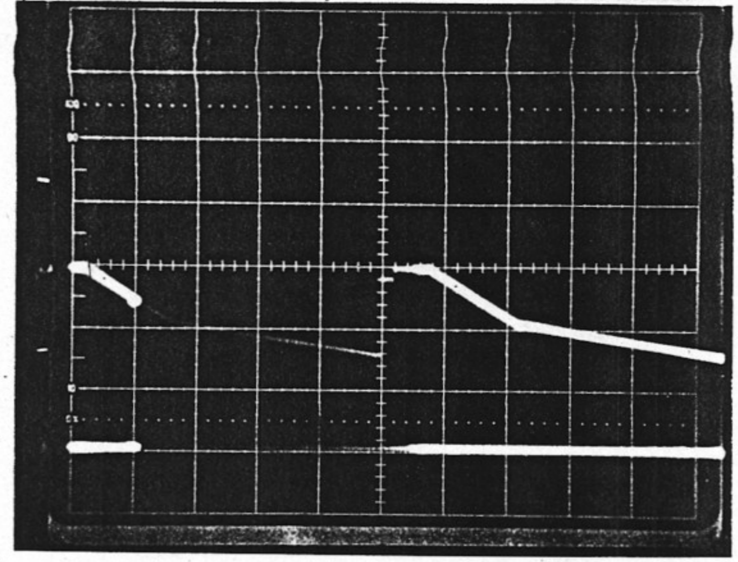
	AREA	EQPT	REQUEST	READBACK
1	SEB	CP1A	-1295	10MS TZERO
2	SEB	CP1T	2 ON	10MS TZERO
3	SEB	CP1S	3 LIN	10MS TZERO
4	SEB	CP2A	-500	10MS TZERO
5	SEB	CP2T	190 OFF	10MS TZERO
6	SEB	CP2S	800 LIN	10MS TZERO
7	SEB	CP3A	62	10MS TZERO
8	SEB	CP3T	14 OFF	10MS TZERO
9	SEB	CP3S	0 LIN	10MS TZERO
10	SEB	CP4A	0	10MS TZERO
11	SEB	CP4T	100 OFF	10MS TZERO
12	SEB	CP4S	4 LIN	10MS TZERO

Figure 2 b



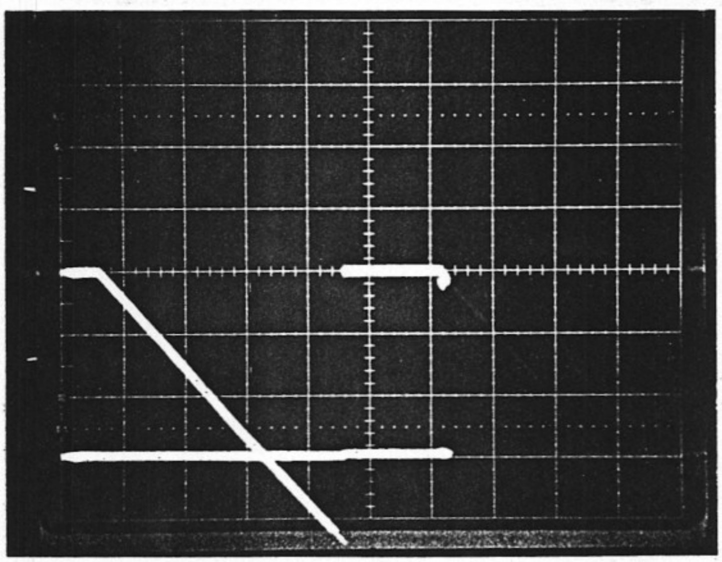
A2 RMP

2 V/div, 0.2 s/div, Tr = 400 ms



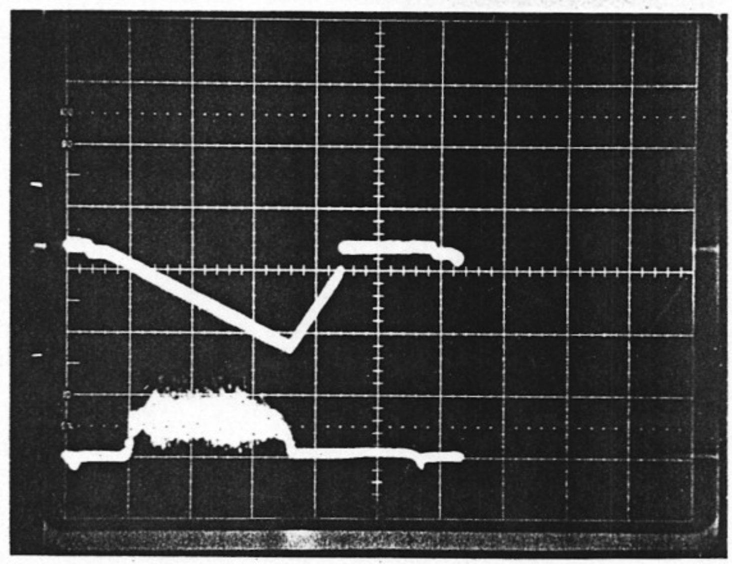
A5 RMP

2 V/div, 0.5 S/div, Tr = 200 ms



B4 RMP

1 V/div, 0.5 S/div, Tr = 200 ms

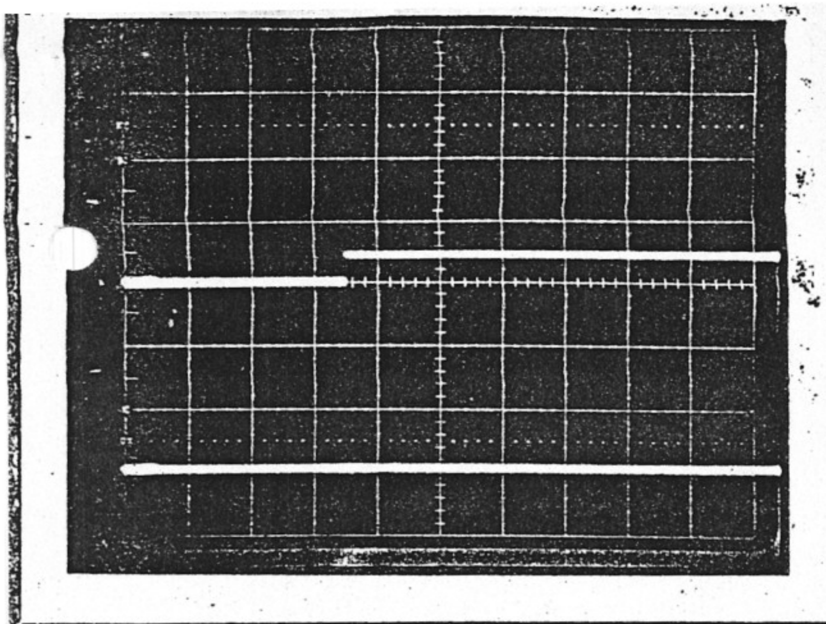


B5 RMP

U: 0.5 V/div, 0.5 S/div, Tr = 200 MS

L: CE010 BEAM SPILL

Figure 3a



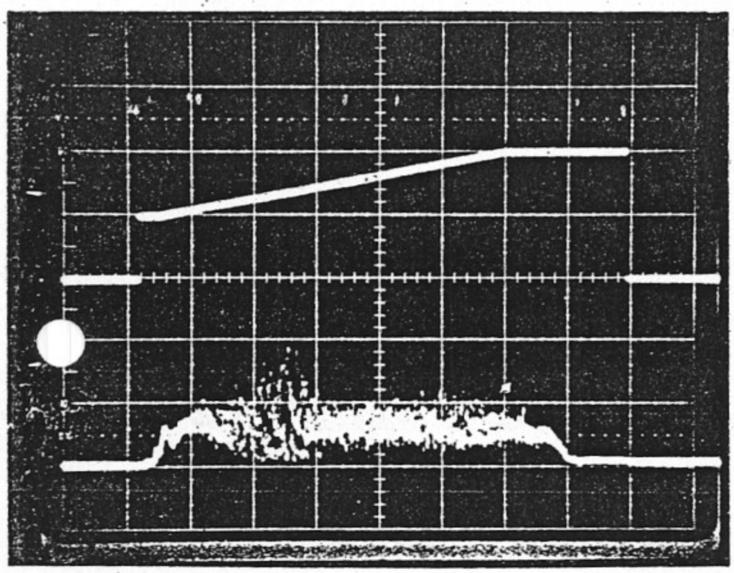
C1 RMP

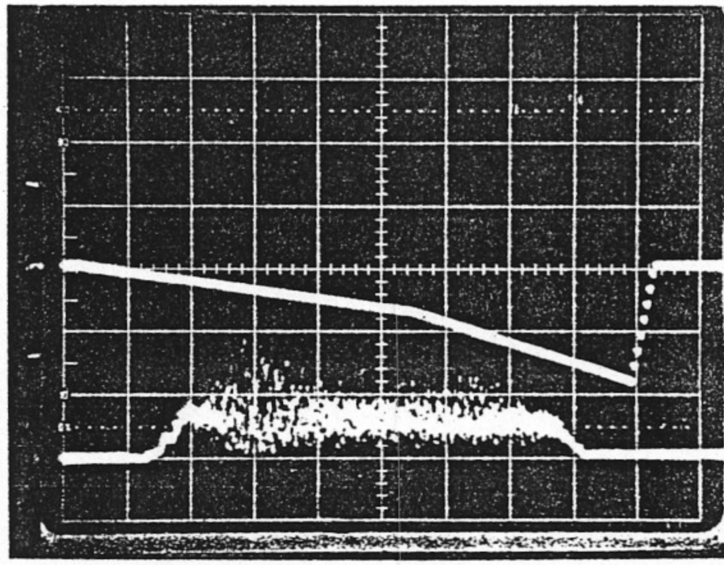
1V/div, 0.2S/div, Tr=200ms

D7 RMP

5V/div, 0.2S/div, Tr=400ms

L: CED10 BEAM SPILL

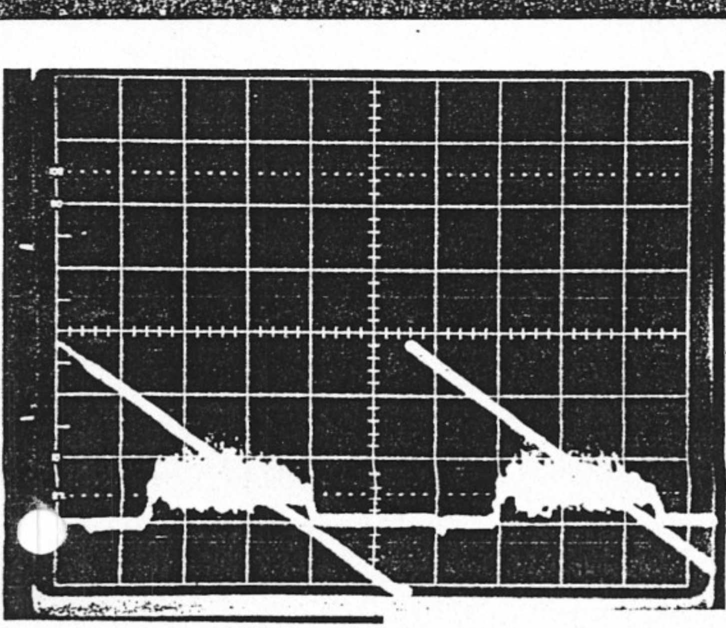




DE RMP

1V/div, 0.2S/div, Tr=400ms

L: CED10 BEAM SPILL



CP RMP

1V/div, 0.5S/div, Tr=0

L: CE010 BEAM SPILL

Figure 3 6

UPPER CONNECTOR (TAPER PIN)

K-LOC Connectors		Pin		Signal
	A	1	————	COM
	← ← ← ← ← ← ←	4	————	RUN
	← ← ← ← ← ← ←	6	————	STOP
	← ← ← ← ← ← ←	8	————	EXT CLOCK
		21	————	SCOPE TRIG
		22	————	COM
	A	A	————	COM
	← ← ← ← ← ← ←	F	————	OUTPUT
		J	————	+ 5V
		L	————	- 15 V
		P	————	+ 15 V
		Z	————	COM

CRATE CONTROLLER		LOWER CONNECTOR (WIRE WRAP)		
	B	A	————	COM
B10	————	B	————	MSH ADDR
B2	————	C	————	LSH ADDR
B3	————	D	————	" "
B21	————	H	————	R/S
		J	————	+ 5V
		L	————	- 15 V
BE	————	M	————	ACCEPT PULSE
AS	————	N	————	REPLY PULSE
		P	————	+ 15 V
BX	————	V	————	ALL INFO
BV	————	W	————	CLOCK
A8	————	X	————	DATA GP I } REPLY
A16	————	Y	————	DATA GP II } REPLY
		Z	————	COM

Figure 4. Function generator signal lines and connections.