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Beam Losses Associated with the Booster-to-AGS Transfer and AGS Accumulation (1995)

K. Zeno

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Collider Accelerator Department

Brookhaven National Laboratory

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Participants: K. Zeno, B. Tamminga, L. Ahrens
Reported by: L. Ahrens
Machines: Booster and AGS
Tools: Booster "injection" and current transformer, AGS "CERN" F15 current transformer, LeCroy digital scope

Introduction

This note gives a brief tabulation of beam losses associated with the transfer and accumulation process between the Booster and AGS for high intensity proton running. The situation corresponds to high intensity machines (19 TP Booster late and 53 TP AGS injection porch late), although not the very highest. A lower intensity data dump is also included. The primary source for the loss measurements are the current transformers in each machine. The data, taken at face value, imply that the largest fraction of beam loss is never seen by the transformer in the AGS - either never getting into that machine or getting lost too quickly for the transformer to respond. The position where that loss occurs is not identified by this data.

Procedure

Both the AGS and the Booster are instrumented with current transformers. In Booster, for this note, only the intensity just at extraction is relevant. To avoid hidden offset problems, the unnormalized "injection" current transformer is used to determine the intensity just before extraction on each of the four transfers. The step down at extraction in the output from this device is measured. The absolute calibration is obtained by measuring the response to a known current calibration pulse which can be sent to the transformer. The extraction step height is measured on each of the four transfers to AGS.

In AGS (see Figure 1), the evolution of the surviving beam over the four transfers is as important as the step gain at each of the four transfers. Here the intensity measurement is made using the "CERN" current transformer, located at straight section F15, frequency normalized, and digitized to allow extraction of losses for a set of times across the injection porch. A calibration pulse is again available. A set of readings are taken around each transfer. Specifically, a reading is taken 2 ms before the transfer, just before the output begins to rise due to this transfer, just after the rise is finished - at the peak, and 2 ms after the rise is finished. With these (4)x(4) readings, and one at the end of the porch, the visible losses can be grouped by time of occurrence into those happening shortly before and after a transfer, and those happening between transfers. The choice of 2 ms was driven by the typical appearance of the current transformer wave form, with the slope changing significantly over this 2 ms time but very little thereafter. The rise time for this AGS transformer is about 40 μsec to 90%, or 14 turns, so losses over the first few turns are barely seen. All of the data is taken by the digital scope on a single AGS cycle. Figure 1 gives pictures of a typical scope acquisition from which the numbers are extracted. The upper display gives the current transformers in both machines on a slow time scale (200 ms/box) with the four transfers as well as transition and half of the extraction ramp visible. (The Booster current function shown actually comes from the normalized transformer while the unnormalized transformer was used for the data presented in this note.) The lower trace uses the data saved in the upper figure and redisplays this on a much finer (1 ms/box) time scale with each transfer shown separately.

Data and Discussion

A single data dump, with 53 Tp at the end of the AGS front porch is presented in Table 1. This is not an average, it is not the flat out machine, but it is claimed to be representative.

Intensity in TP	Booster Late	AGS Step Gain	+/- 2ms Loss	Drool Loss
1st trans	20.34	16.27	1.77	.3
2nd trans	18.60	14.82	1.48	.66
3rd trans	18.97	15.59	1.43	.72
4th trans	19.22	15.50	1.95	.47
sum	77.12	62.17	6.63	2.14
% of Booster Late	100%	80.6%	8.6%	2.8%
% of AGS Peak		100%	10.7%	3.4%

Table 1. High Intensity Transfer Survival

The subset of this data most easy to believe are the relative numbers coming only from the AGS transformer. Here 3.4% of the beam seen in the AGS is lost in the "drool" fashion, and 10.7% is lost in the +/- 2 ms around the four transfers (called "slow" losses here). This last category would include any slow loss associated with the pulsing of the injection bump, perhaps beam which has "diluted" into the aperture being wiped off by the bump. It might well not include fast losses associated with the "tail biting" of the A5 kicker (which we will call "fast" or "beamline like" losses) because of the response time of the transformer. Rather, these losses would only be visible in comparing the surviving "peak" AGS beam with transformers upstream. The cause for these certain drool and slow losses is open for debate. The behavior of a lower intensity situation (Table 2) is relevant to this discussion. Stop band losses may be involved for both the drool and slow losses. The tuning of the two octupoles added to the ring last year greatly affected and even greatly reduced the drool category loss.

If one moves on to assume that the transformers in the two machines have identical calibration, the emphasis changes. Now the relevant beam for normalization is that measured at Booster extraction. The possible loss points and mechanisms include losses in the Booster at extraction, losses in the BtA, and fast beamline like (few turn) losses in AGS in addition to the mechanisms mentioned above. The rather sobering conclusion, with these assumptions is that this category of losses is the dominant one - responsible for a 20% beam loss, while the slow and drool losses are an additional 10%.

The losses - loss monitor response - associated with this huge fast loss are not easy to find. Indeed attempts to find them have not been successful but the subject is not closed. If the loss is spread around the AGS, that might not be too surprising. If it were concentrated in the transfer line it should be obvious.

Just to give a bit more complete glimpse into the situation, Table 2 reports the results from a "low intensity" AGS cycle - 20 Tp in AGS as the end of the porch. Again this is just one cycle, with BtA tuned to be as efficient as possible within the time available.

TP	Booster Late	AGS Step Gain	+/- 2ms Loss	Drool Loss
1st trans	4.69	3.94	.1	.06
nd trans	4.95	4.35	.1	.01
3rd trans	4.82	4.27	.1	0
4th trans	4.78	4.3	.21	.06
sum	19.24	16.85	.51	.13
% of Booster Late	100%	87.6%	2.7%	.7%
% of AGS Peak		100%	3.0%	.8%

Table 2. Low Intensity Transfer Survival

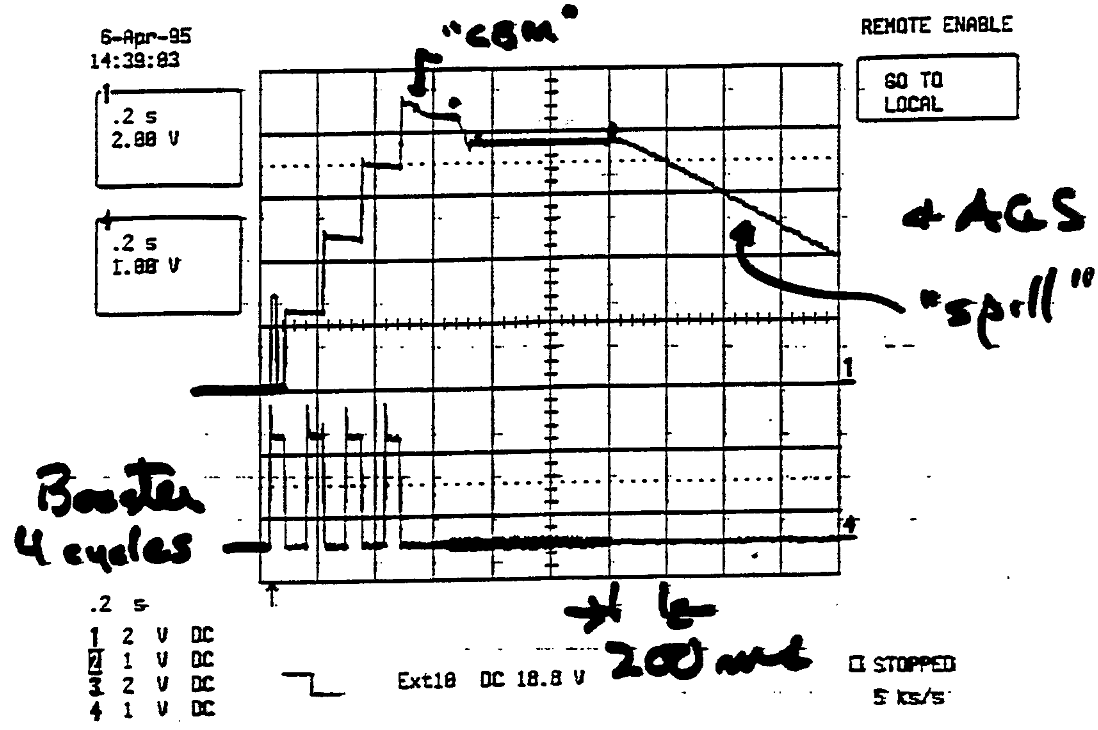
Further Discussion, Future Plans

The search for loss monitor signals associated with the transfer loss is not a finished subject. It requires accurate loss monitor calibrations, nonsaturating monitors, well defined machine conditions. The improvements to the AGS loss monitor system which are under way should help in these regards. Calibrations for the AGS system at injection should be made. The calibrations for the Booster and BtA loss monitors should be checked.

The current transformers in both machines require ongoing calibration checking. Booster generation transformers in the AGS should have rise times corresponding to just a few turns and so should help clarify the situation. These transformers with this sort of rise time were not available when the above data was taken. The current transformers in the BtA line add intensity measurements at very relevant points. For this information to be useful, its absolute accuracy needs to be at the 1% level. These transformers have calibration pulse facilities.

The generation of data such as that presented in the above tables in real time, with the ability to average over several AGS cycles should be available to us this year (Tamminga). Combining such data with loss monitor data from the same cycle may be possible, and would help clarify the situation, especially if tight correlations between current transformer losses and loss monitor losses can be found.

Intensity vs time



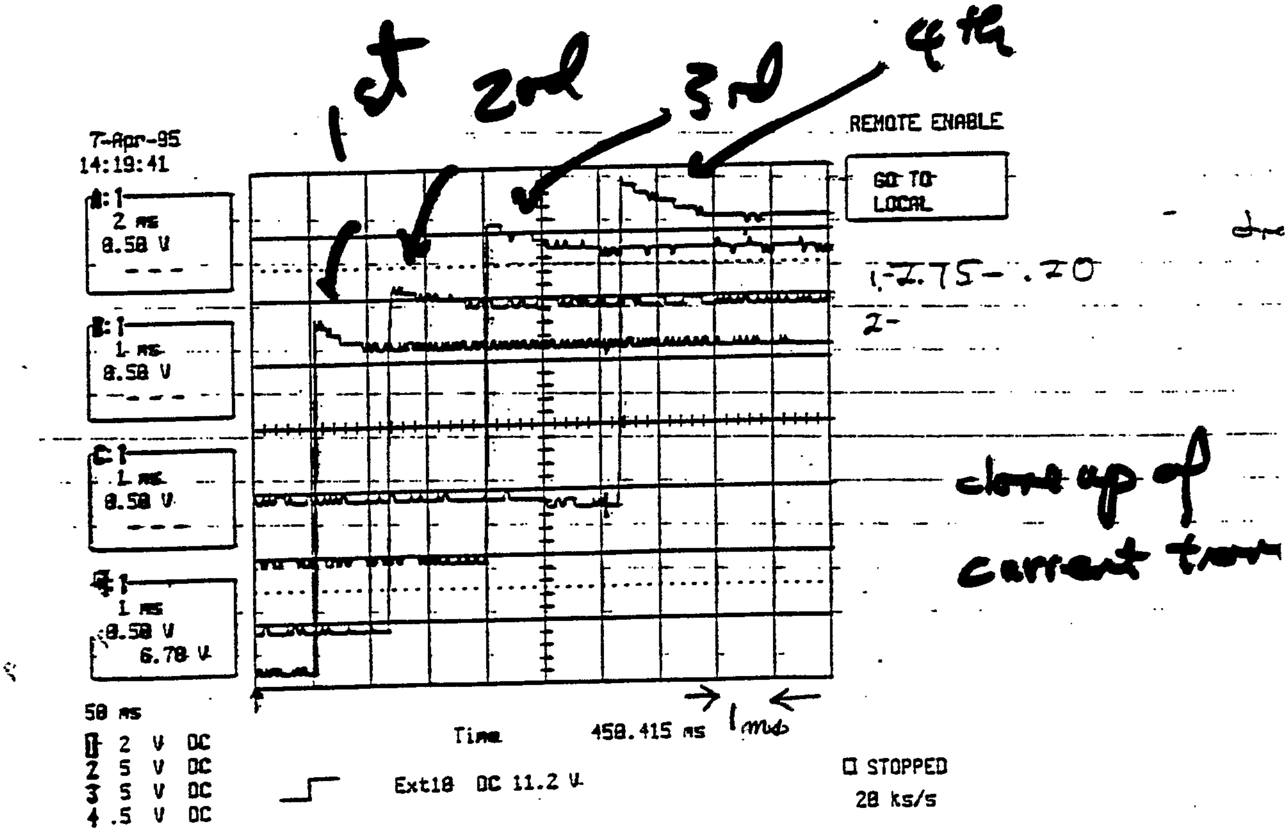


Figure 1.