STACKING WITH A MISSING-BUCKET IN CESAR.

E. Jones, L. Magnani

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1. Introduction

This note is to be considered preliminary because careful measurements of stacking efficiency were not made, primarily because the vacuum in CESAR was only $4 \times 10^{-9}$ torr thus limiting the half lifetime of a circulating beam to approximately 0.5 sec. and the number of pulses stacked to at most 40.

A secondary reason is that the form of the R.F. voltage applied to the cavity is not as good as it might be, the ideal signal being a sine wave with every other period missing whereas in practice the signal was as shown in figure 1. However, the errors introduced by these technological difficulties are ignored for the moment and the experiment is to be considered as a first attempt to stack with one bucket missing out of the two normally employed in CESAR.

A more careful series of measurements with missing buckets is to be carried out in the near future when the pressure in the vacuum chamber is expected to be reduced to a few times $10^{-10}$ torr.

2. Experiment and Conclusion

Two very simple experiments were carried out, and the results are recorded by means of photographs of the scanning bucket signal.

The first experiment, recorded in figure 2, is a direct comparison between the appearance of two stacks — one made up of 20 injected pulses trapped into the normal two bucket R.F. system of CESAR and the other made up also of 20 injected pulses but in this second stack one of the buckets is eliminated. The pulses were always injected into moving buckets. This means that at least half the injected pulse is left to circulate at the injection orbit where it quickly decays (due to the very limited aperture) and is finally destroyed completely when the next injected pulse is inflected. This method of injection also implies that the buckets were full.
Examination of figure 2 indicates that the stack width is reduced by a factor of at least 1.4 by means of missing a bucket, whereas in theory, there should be a reduction by two. However, the theoretical reduction is only valid when large numbers of pulses are stacked. Thus, the second experiment attempted to increase the number of pulses stacked with missing buckets by a factor of two, but in this instance comparing the widths of two stacks made up of the same amount of phase space area. The second experiment was carried out as follows:

20 pulses each consisting of two buckets was stacked i.e. the normal R.F. program was used. The scanning bucket was however delayed so that it passed through the stack at a time corresponding to that needed to stack 40 pulses - this means about 0.8 seconds after the first pulse was injected and stacked. The delayed scan was necessary in order to compensate for the effect of our limited half lifetime ($\approx 0.5$ seconds) because in order to stack the same amount of phase space with one bucket missing it is necessary to stack 40 pulses. (The interval between stacking cycles in CESAR is always 20 mseconds).

Figure 3 shows the result of such an experiment and the two stack widths - one consisting of 20 times two buckets and the other of 40 times one bucket - appear to be as nearly equal as can be estimated with stacks having such long tails. This tail is, of course, introduced by the loss of beam due to gas scattering - at the time of the scan the first pulse stacked in both photographs, has circulated in the machine for 0.8 seconds and its intensity therefore reduced to well below a half of its initial value!

One can conclude that stacking with missing buckets is certainly feasible and that stack widths and therefore densities in the ISR's will certainly benefit from the elimination of all empty buckets. The buckets will in fact not be "missed"!

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Fig. 1  R.F. signal for the missing bucket programme

The stacking bucket parameters are in all cases:

\[
\text{R.F. voltage (peak)} = 1.8 \text{ V} \\
\hat{T} = 11 \text{ KeV/msec}
\]

\[
\left(\frac{A}{2\pi}\right) \text{ normal} = 1.6 \text{ KeV} ; \quad \left(\frac{A}{2\pi}\right) \text{ missing} = 0.8 \text{ KeV}
\]

The scanning bucket parameters are in all cases:

\[
\text{R.F. voltage (peak)} = 3.5 \text{ V} \\
\hat{T} = 21 \text{ KeV/msec} \\
\Delta E_B = 6 \text{ KeV}
\]
Fig. 2 Scanning signals — to be compared in width only, the differences in height are attributable to fluctuations in trapping efficiency.
Fig. 3  Scanning signals observed 0.8 seconds after commencement of injection. Theoretically, stack widths should be equal.