MODEL OF ANTIPROTON STACK SIZE VERSUS RAPID TRANSFER TIME

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INTRODUCTION

This note describes a simple stacking model to examine the trade-offs between Combined Shot operations and Recycler Only operations. The model ignores the effects of emittances, transfer efficiency as a function of stack size, and stacking downtime.

STACKING RATE AS A FUNCTION OF STACK SIZE

Because of transverse heating of the Accumulator Core by the Accumulator Stacktail system, the stacking rate decreases as the stack size grows [1]. A reasonable model for the stacking rate as a function of stack size is given as:

$$\frac{dS}{dt} = R_o\left(\frac{S_{max} - S}{S_{max}}\right) \tag{1}$$

where R_o is the stacking rate with no stack and S_{max} is the stack size at which the stacking rate drops to zero. This simple linear approximation ignores the effect of antiproton cycle time on Debuncher cooling. Equation 1 can be integrated to give:

$$S(t) = \left(S_{max} - S_o\right)\left(1 - e^{-\frac{R_o t}{S_{max}}}\right) + S_o \tag{2}$$

where S_o is the stack size at t=0. The total stack size in the Recycler after n_{int} transfers is:

$$S_{rec} = x_e n_{int}\left(S_{max} - S_o\right)\left(1 - e^{-\frac{R_o\left(T_{int} - \Delta\tau\right)}{S_{max}}}\right) \tag{3}$$

where T_{int} is the period between transfers to the Recycler, $\Delta\tau$ is the time it takes to do the transfers, and x_e is the transfer efficiency. The amount of stack left behind in the Accumulator is S_o. The amount of stack available in the Accumulator for direct transfers from the Accumulator to the Tevatron is:

$$S_{acc} = \left(S_{max} - S_o\right)\left(1 - e^{-\frac{R_o\left(T_{tot} - n_{int} T_{int}\right)}{S_{max}}}\right) \tag{4}$$

where T_{tot} is the total amount of time in between Tevatron shot setups. To fill the Tevatron, there is a total of nine transfers of four antiproton bunches. Neglecting differences in emittances, it is desirable to have the intensity of each bunch the same:

$$S_{acc} = \frac{M}{9 - M} S_{rec} \tag{5}$$

where M is the number of transfers between the Accumulator to the Tevatron.

Again neglecting differences in emittances, the Tevatron luminosity is proportional to the total amount of antiprotons available to the Tevatron. For a given set of stacking parameters, total stacking time, and transfer time, there is unique combination of the number of Accumulator to Recycler transfers and Accumulator to Tevatron transfers that maximize the total amount of stack available to the Tevatron. This combination is shown in Figures 1 and 2. The Accumulator to Recycler transfer interval and the amount of antiprotons in the Accumulator available to the Recycler is shown in Figures 3 and 4. The stack in the Recycler and the total stack available to the Tevatron are shown in Figures 5 and 6.

As shown in Figure 2, Combined Shot operations with one or more transfers coming from the Accumulator to the Tevatron will always maximize the amount of antiprotons available to the Tevatron. However, Figure 7 shows that the gain of Combined Shot operations to Recycler Only operations is no better than 12% under the worst conditions (low stacking rate and long transfer times). As a comparison, Figure 8 shows the gain of Recycler Only operations to Accumulator Only operations. For low stacking rates and long transfer times, Recycler Only operations and Accumulator Only operations are about the same. Figures 9-12 show total stack size, number of transfers, transfer interval, and transfer size for Recycler Only operations.

REFERENCE:

"Antiproton and Neutrino Production Accelerator Timeline Issues," Dave McGinnis, Beams Document No. 1941, August 28, 2005.

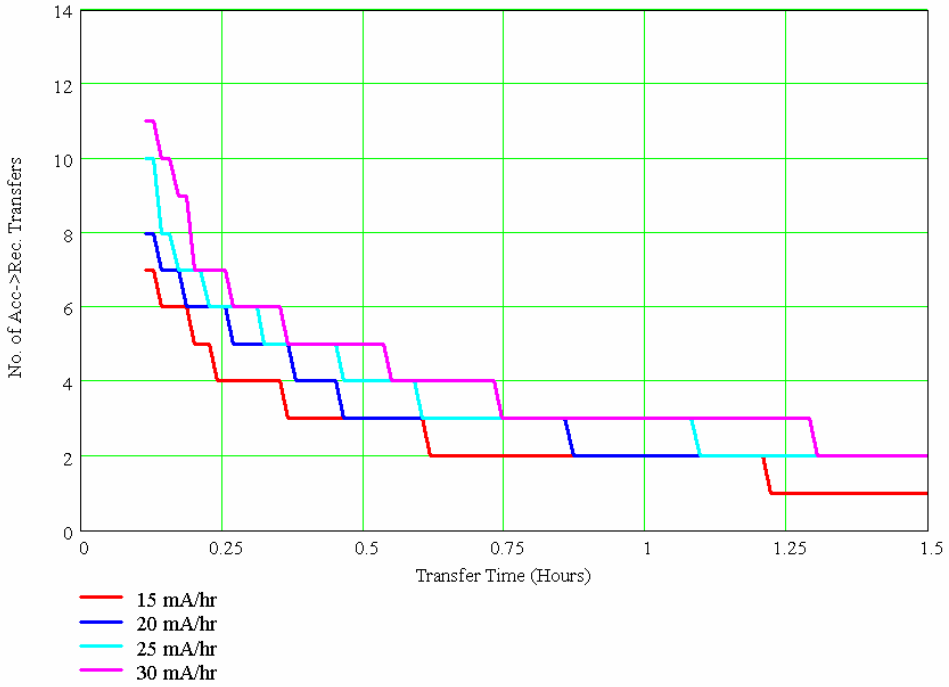

Figure 1. The number of Accumulator to Recycler transfers vs. the time it takes to transfer antiprotons to the Recycler for Combined Shot operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

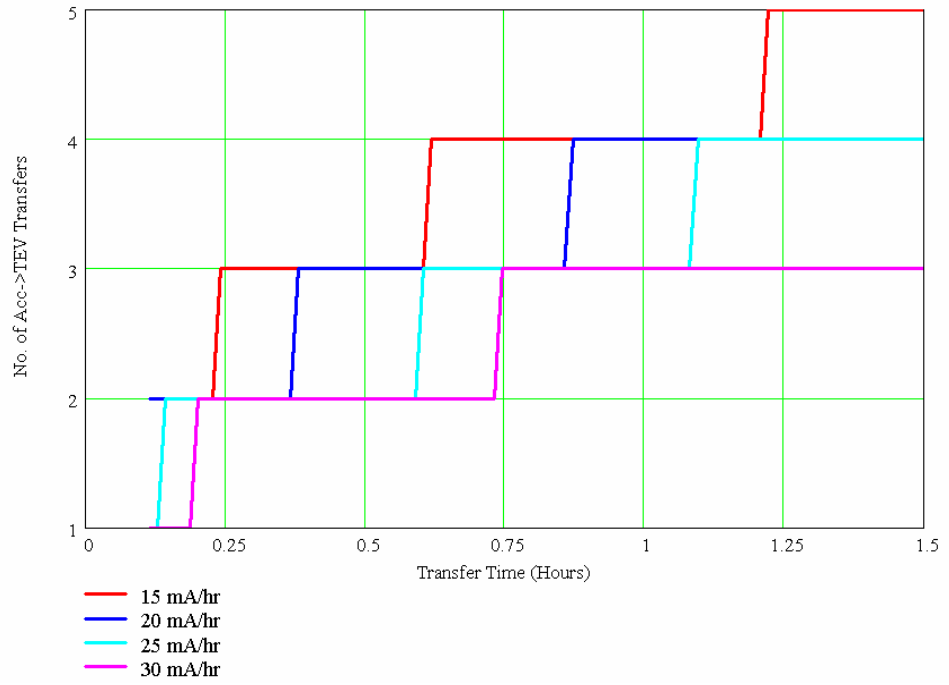

Figure 2. The number of Accumulator to Tevatron transfers vs. the time it takes to transfer antiprotons to the Recycler for Combined Shot operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

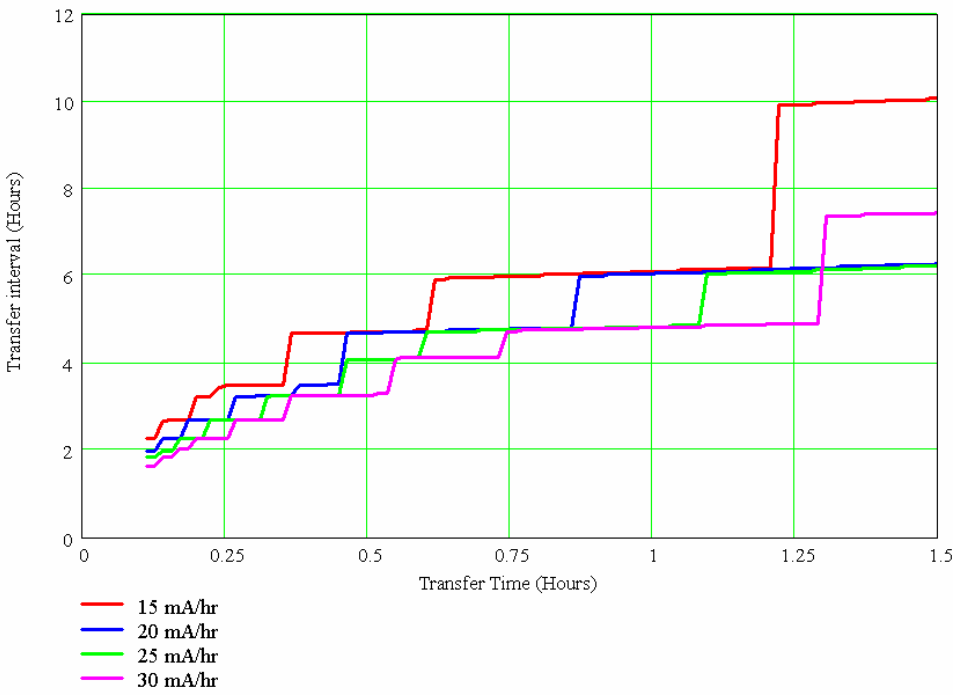

Figure 3. The transfer interval for transfers to the Recycler vs. the time it takes to transfer antiprotons to the Recycler for Combined Shot operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

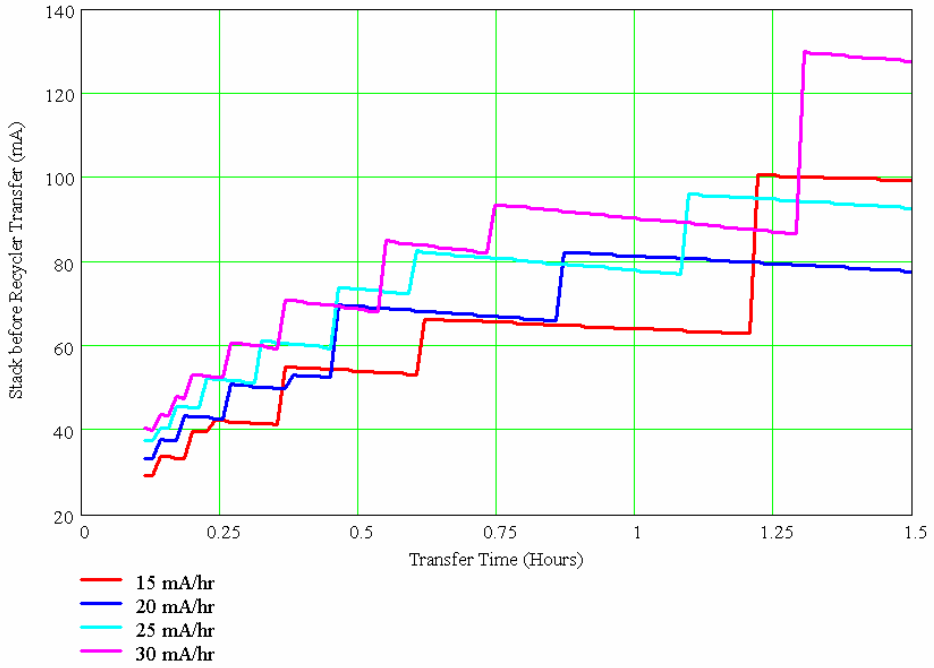

Figure 4. The stack in the Accumulator available for transfers to the Recycler vs. the time it takes to transfer antiprotons to the Recycler for Combined Shot operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

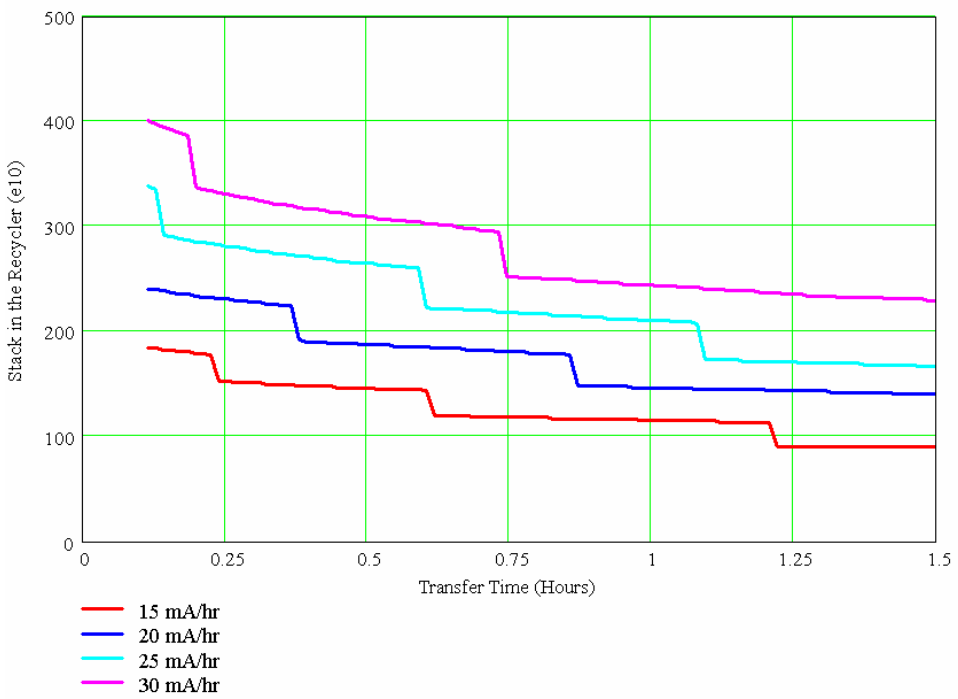

Figure 5. The stack in the Recycler available for transfers to the Tevatron vs. the time it takes to transfer antiprotons to the Recycler for Combined Shot operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

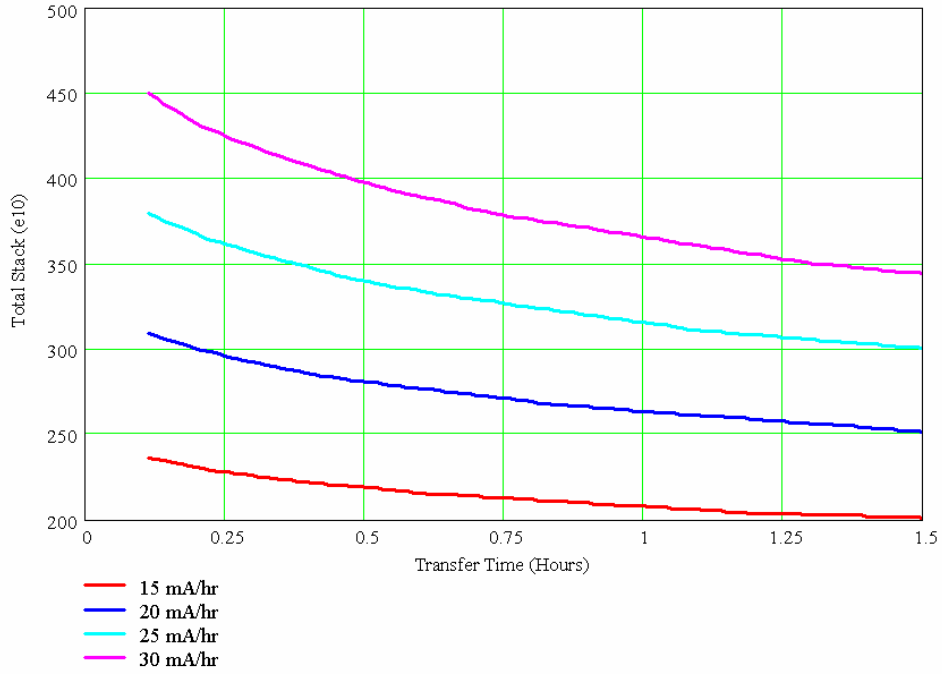

Figure 6. The total stack available for transfers to the Tevatron vs. the time it takes to transfer antiprotons to the Recycler for Combined Shot operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

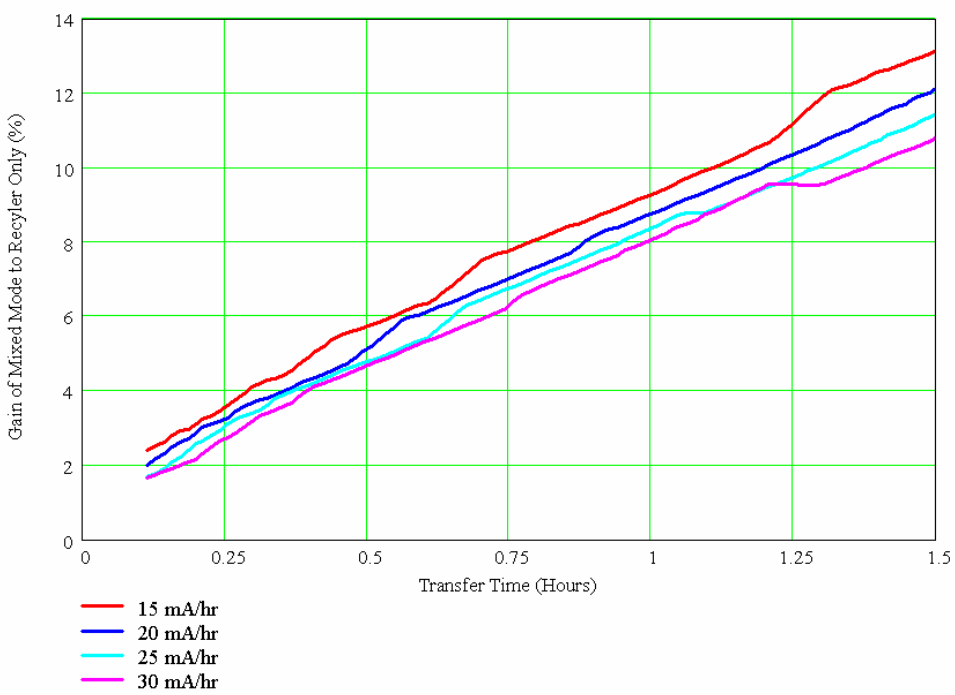

Figure 7. Percentage gain of Combined Shot operations to Recycler Only operations vs. the time it takes to transfer antiprotons to the Recycler. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

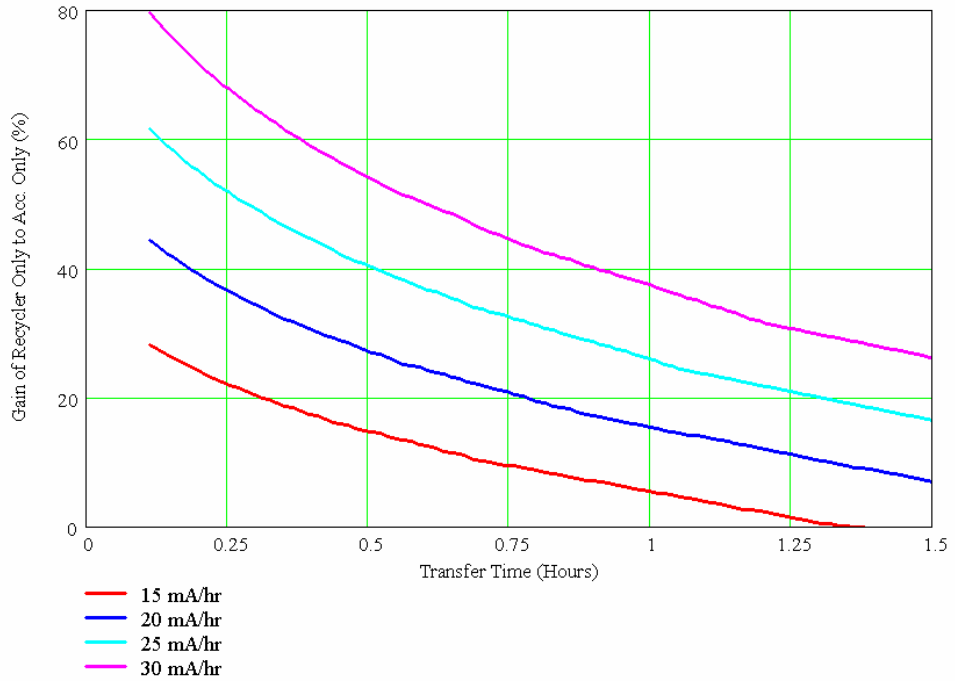

Figure 8. Percentage gain of Recycler Only operations to Accumulator Only operations vs. the time it takes to transfer antiprotons to the Recycler. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

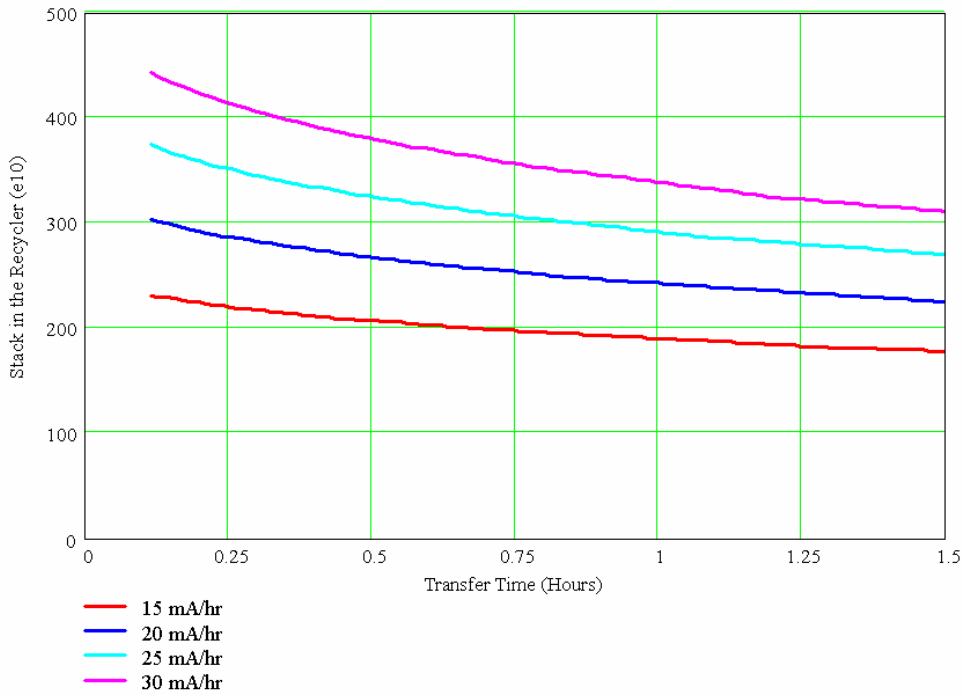

Figure 9. Amount of stack in the Recycler available to the Tevatron vs. the time it takes to transfer antiprotons to the Recycler for Recycler Only operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

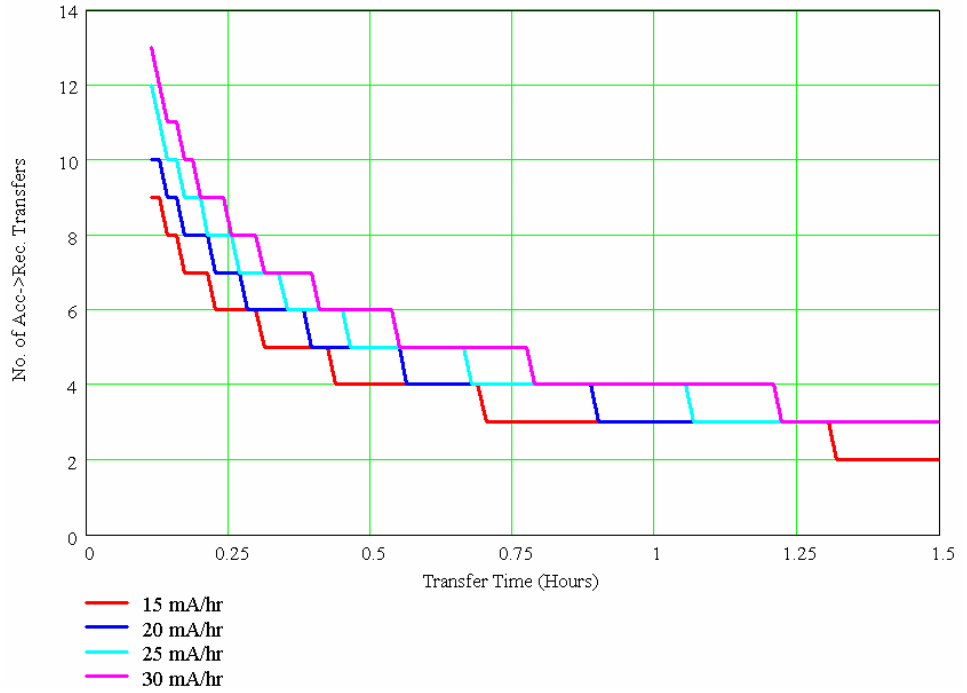

Figure 10. The number of Accumulator to Recycler transfers vs. the time it takes to transfer antiprotons to the Recycler for Recycler Only operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

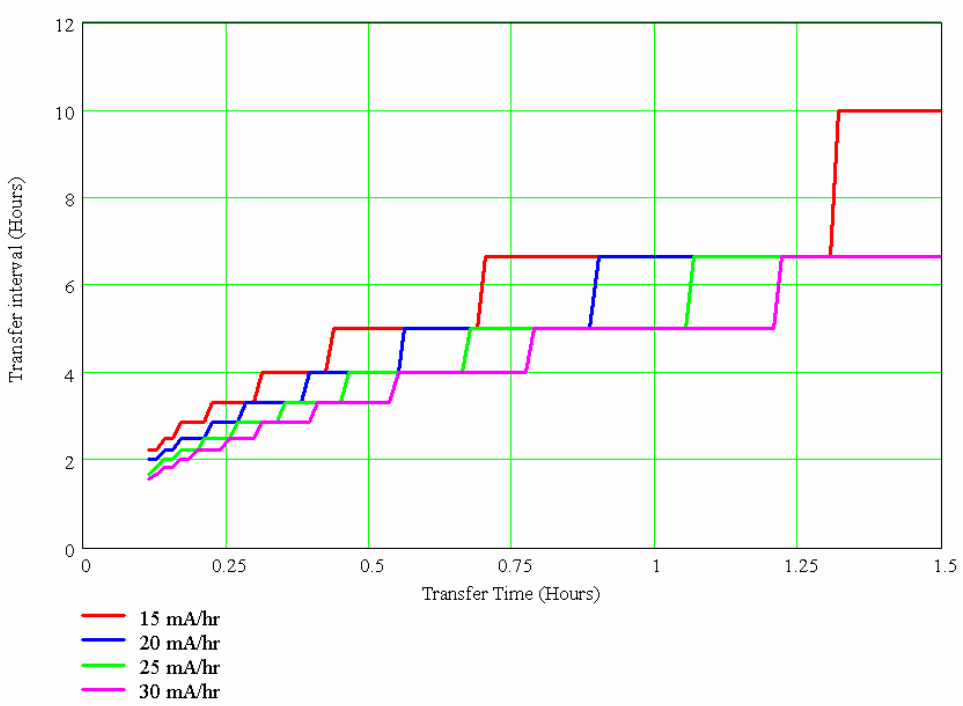

Figure 11. The transfer interval for transfers to the Recycler vs. the time it takes to transfer antiprotons to the Recycler for Recycler Only operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%

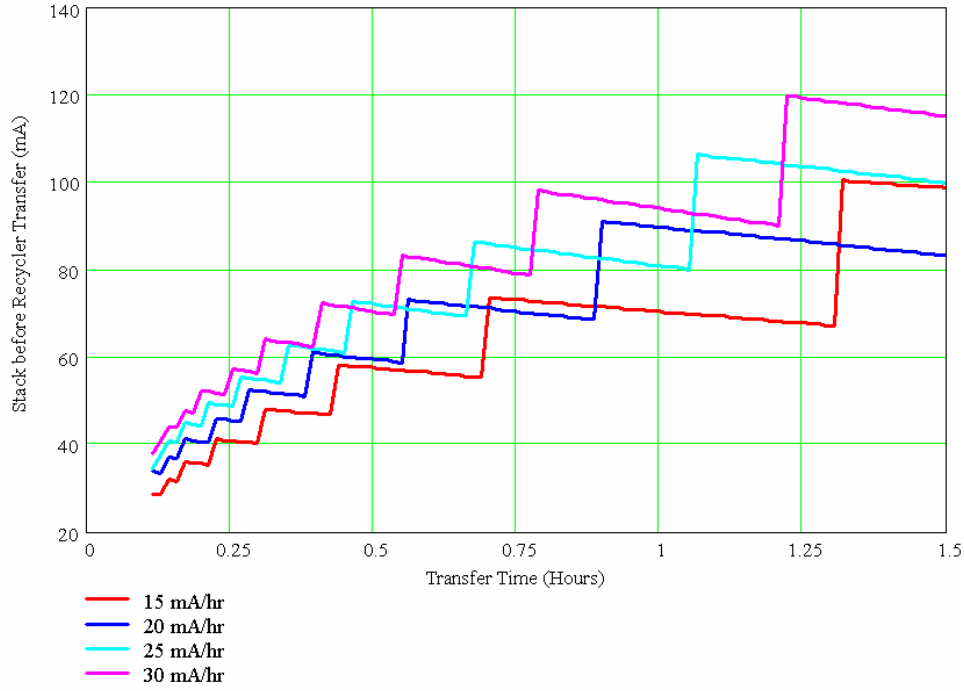

Figure 12. The stack in the Accumulator available for transfers to the Recycler vs. the time it takes to transfer antiprotons to the Recycler for Recycler Only operations. The total stacking time is 20 hours, S_{max}=300mA, and the transfer efficiency to the Recycler is 90%