Magnet Inventory / Excitation Analysis

Charlie N. Igwekala
Electrical Engineering Major

Chicago State University
Chicago, Illinois 60628

Project Supervisors:
Elvin Harms
Steve Werkema

Fermi National Accelerator Laboratory
Batavia, Illinois 60510

August 8, 2002

Abstract:

An inventory is a catalog of items. The Magnet Inventory entailed amassing information on the magnets present within the Antiproton Source. It has been expressed that knowledge of magnets in operation is necessary to improve upon the efficiency of the Antiproton Source and any alterations to be made from here on. Within the boundaries of creating this inventory are the needs of manageability, safeguards on accidental alteration of data, and accuracy in regards to the location of magnets.

Excitation is a term related to the behavior exhibited in a magnet. More specifically, it relates to the strength of the magnetic field as the magnet is "ramped," while changing the current supplied to it. After all the data is

collected from the magnets, an excitation analysis is to ensue. The basis for the creation of the excitation analysis is to provide a visible difference between the "up ramp" and the "down ramp" of a magnet. Further requirements involved assembling graphical interpretations of specific types of magnets. These interpretations would include a data fit, along with the ability to pinpoint errors in the specifications of a magnet in relation to this databased "average".

It is the purpose of this paper to provide a detailed account of how the inventory of the Antiproton Source was performed and what degree of success the inventory encountered. Furthermore, this paper will elaborate on the methods utilized to generate an excitation analysis on the Pbar magnets.

Introduction:

To fully understand the significance of the Magnet Inventory and Excitation Analysis would require knowledge of what is done at the Fermilab Antiproton Source. Otherwise known as the "pbar" source, the Antiproton Source is extremely vital to the high-energy physics performed and the Fermi National Accelerator Laboratory. The collisions in the accelerator used to occur with particles in motion colliding with a target at rest. This system produces a low center of energy mass since all the energy comes from one source [particle in motion].

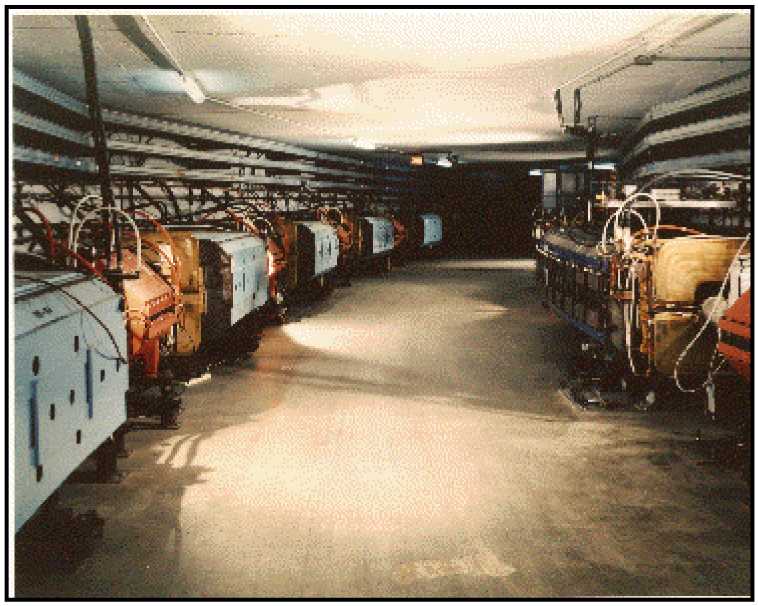

Figure 1:
A picture inside the tunnel of the Antiproton Source. Roughly 20 feet under the ground, antiprotons are injected into the Antiproton source from the AP2 line into the Debuncher (Left ring of magnets). On the right is the Accumulator ring, where the antiprotons are stored in what is called the "core".

It is important that collisions take place between objects of relative mass in order to generate productive center of mass collision energy. Otherwise, within collisions of greatly differing masses, one particle is simply eradicated. With this thought sequence, the benefits of matter and anti-matter are introduced.

Matter and anti-matter, though sharing an identical mass, bear opposite charges. If implemented, a matter / anti-matter accelerator would yield more violent collisions than the previously commissioned procedure, with the factor of the collisions determined by the energy of the injected particles. Application of a high energy accelerator utilizing particles and their anti-matter counterparts achieves these collisions due to the momentum of two particles in equal but opposite velocities.

Antiproton Process:

Understanding the necessities of the collisions desired at Fermilab, it is important to obtain both the matter and the anti-matter that is to be collided. By stripping hydrogen atoms of their electrons and accelerating them to 120 GeV in the Main Injector, a batch of protons can be obtained. However, anti-matter is not as easily acquired. Since anti-matter does not exist naturally in our universe, it must be created. A batch of protons is accelerated towards a target vault, where these protons impact a nickel production target. From this collision comes an array of secondary particles, which are focused by what is referred to as the Collection Lens. This lithium lens focuses the spray of particles into parallel paths. Negatively charged particles at the specific energy of 8 GeV [antiprotons] from the collision are deflected by a pulsed dipole magnet while the excess particles are absorbed into a beam dump.

The diverted beam of antiprotons now proceeds down the AP2 line and injected into the Debuncher where the momentum spread of the particles is reduced by the processes of bunch rotation and adiabatic debunching. In addition, betatron stochastic cooling and momentum cooling are applied to the particle beam to reduce the beam size and further reduce the momentum spread. Additionally, transverse cooling systems act upon the beam within the core. Finally, before the next pulse of antiprotons arrives in the "Pbar" source, they are extracted from the Debuncher and injected into the Accumulator by way of the D to A line. Using RF deceleration and momentum stochastic cooling, pulses of antiprotons are stacked towards the Accumulator "core". Once in the core, it might be necessary to maintain the antiprotons for hours, days, or even weeks before injection into the Main Injector and the Tevatron.

Theory:

A brief look into the properties of light will reveal that light rays tend to spread out from their source. Similarly, in a high-energy accelerator, the beam within tends to expand vertically and horizontally as time progresses. To compensate for this occurrence, there must be some form of confinement or a way to focus the beam while en route towards the collision site. Furthermore, the manner in which the antiprotons are to be harnessed requires a circular path. This produces a need for not only beam size reduction, but path alterations as well. To accomplish these tasks, the Antiproton Source uses magnets specific to its needs at various junctures throughout the tunnel.

The Magnets:

The Antiproton Source utilizes various styles of magnets to generate different effects upon the beam path. Dipoles are used in order to deflect or bend the beam path. To constrain the beam size, quadrupoles are placed along the antiproton beam path to reduce the beam size horizontally and vertically. Other corrections to field errors pertaining to the dipoles and quadrupoles, plus the high-order beam qualities can be made with magnets consisting of varying sizes and greater numbers of magnetic poles.

The placement of the beam, the correct beam size, and the proper vertical and horizontal reduction of the beam cannot be accomplished without knowledge of the characteristics of all magnets currently commissioned. Moreover, knowing the properties of magnets in storage is also vital, especially in the event that a magnet needs to be replaced. Here lies the stress upon an up-to-date magnet inventory.

Inventory:

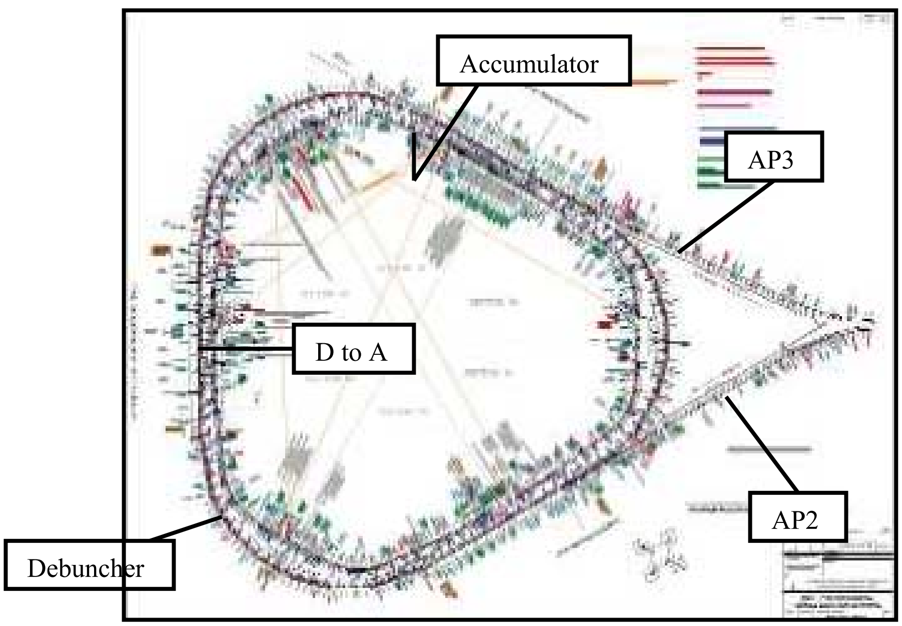

Figure 2:
A thumbnail schematic of the Antiproton Source. Accumulator circumference (inner ring) is 474 meters, and the Debuncher circumference (outer ring) is 505 meters.

There are exactly six hundred sixty-eight magnets within the Accumulator, Debuncher, AP1, AP2, AP3, and D to A lines. From these, data was collected in regards to magnetic qualities exhibited at particular junctions of the antiproton source. Characteristics such as resistance, capacitance, inductance, and diameter of the magnets were recorded and evaluated. Within Microsoft Excel, I created a database that is readily accessible to the members of the Pbar department.

SQB							
Magnet Designation	**Magnet Type**	**Serial #**	**L_S**	**Q**	**R**	**C_P**	**D**
IQ16	SQB	SQB002	26.8 mH	2.8	0.0374 Ω	7.223 nF	0.1876
IQ18	SQB	SQB005	27.4 mH	3.0	0.0377 Ω	7.453 nF	0.0045
IQ19	SQB	SQB006	27.4 mH	3.0	0.0373 Ω	7.934 nF	0.0370
IQ20	SQB	SQB010	27.6 mH	3.0	0.0373 Ω	6.809 nF	0.0231
IQ21	SQB	SQB011	27.5 mH	2.98	0.0372 Ω		
IQ23	SQB	SQB012	27.7 mH	3.0	0.0375 Ω	6.945 nF	0.0480
EQ4	SQB	SQB013	27.5 mH	3.0	0.0372 Ω	6.938 nF	0.0133
EQ19	SQB	SQB015	26.9 mH	2.8	0.0374 Ω	7.648 nF	0.0456
A1Q1	SQB	SQB008	27.0 mH	2.95	0.0372 Ω	6.859 nF	0.0065
A2Q1	SQB	SQB004	27.0 mH	2.9	0.0372 Ω	6.62 nF	0.036
A3Q1	SQB	SQB003	27.3 mH	3.0	0.0374 Ω	6.941 nF	0.003
A4Q1	SQB	SQB014	27.3 mH	2.8	0.0373 Ω	6.789 nF	0.0514
A5Q1	SQB	SQB009	27.3 mH	3.0	0.0390 Ω	7.250 nF	0.0138
A6Q1	SQB	SQB007	27.4 mH	3.0	0.0369 Ω		

Figure 3:
Example of database configured from magnetic data

Each spreadsheet within the first file was much like Figure 3, containing information on specifically what magnet [serial number] was at which respective place along the six transport lines. After compiling the data, I applied the most efficient procedures of displaying information available in the software package I implemented. Beyond the data entry, it was requested of me to display the data I gathered graphically. Acknowledging this new parameter of the internship, I proceeded to insert histograms that evaluated the trends present in magnets of the same specific type [Figure 4].

Snag:

At what I felt was a critical juncture during the internship, I experienced of the many bugs rampant throughout a wide range of Microsoft applications. I was inputing data from a section of the Debuncher when Microsoft Excel completely closed down upon my database. Devastated as I was, I attempted to restore the data lost, but that was to no avail. My only recourse was to insert the same data lost for a second time, yet after I reentered the lost section of the inventory into Excel, I quickly searched for a method to secure the cells within my files. Within the Tools menu, there exists a command called Protection. This allowed me to protect a cell, a table or the entire worksheet.

SQB							
Magnet Designation	**Magnet Type**	**Serial #**	**L_S**	**Q**	**R**	**C_P**	**D**
Bin	*Frequency*	*Cumulative %*			**Total:**	15	
26.8	1	7.14%					
27.1	3	28.57%					
27.4	6	71.43%					
More	4	100.00%					

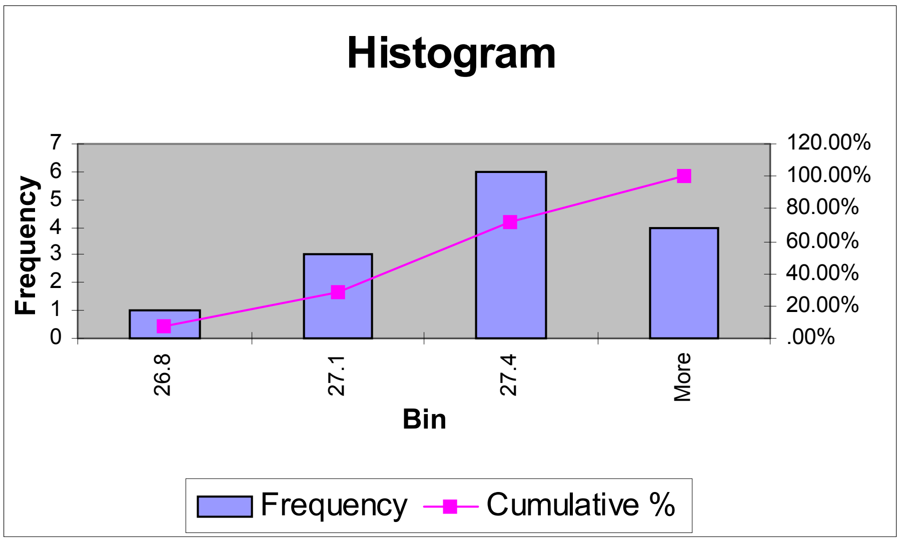

Figure 4: The histogram shown here was generated from information in Figure 3. The table and the graph were tabulated and produced by the data analysis tool found within Microsoft Excel.

Excitation Analysis:

With my file now password protected from outside manipulation in addition to the perils of Microsoft, I performed the Excitation Analysis. This analysis stems from information provided on the net, which soon proved to be extremely difficult to format into the cells of Excel. Each magnet in theory should have information at the Beams Antiproton Department web page:

http://wwwtsmtf.fnal.gov/~dgcw/conv_mag_meas.html

which was compiled by the Fermi National Accelerator Laboratory Magnet Test Facility. From here, I acquired data on magnet behavior from the up ramp and down ramp.

I provided the same file protection that I offered the inventory to the analysis. However in this instance, I used the Chart Wizard feature to create graphs of Magnet Field Strength versus Current Measured [Figure 5]. Each plot of points in Figure 5 represents a data series that had to be manually inserted into the Chart Wizard, since there is no data range sophisticated enough on this particular software package that could evaluate the information I presented.

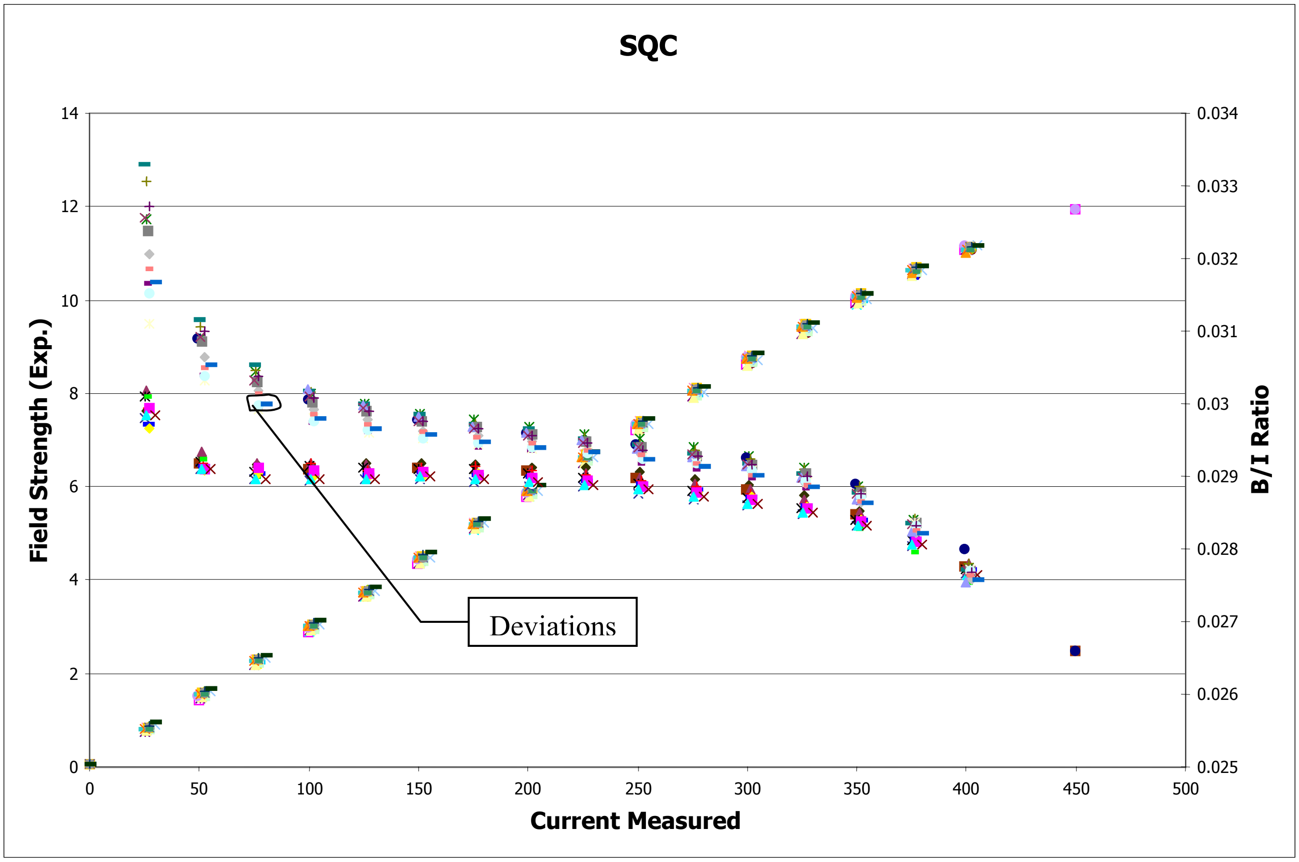

Figure 5:
Example of Excitation Analysis. Compiled from data on the web, this file's intent is to express the differences within the up and down ramp properties of magnets.

Conclusion:

My internship was composed of creating a magnet inventory and evaluating excitations in the various magnets of the Antiproton Source. The data tended to follow trends within the up and down ramp phases, but it is from this that I advise inspection on specific magnets that did not, i.e. those points that deviate from the upper curve [boxed inlet].

In closing, it is of my opinion that some type of program must exist that would have generated more accurate curves for each of the magnet's trends. Further, this program would be able to facilitate the curve fit that I was unable to fulfill. The pitfalls of Microsoft Excel, specifically for forming intricate databases are many, and I would advise strongly against these 'evils' if possible. Excel, in my mind serves for nothing more than your casual spreadsheet with a few pretty features.

Acknowledgements:

I would like to thank Elvin Harms for supporting my academic endeavors into understanding the Antiproton Source. I was able to expound upon my working knowledge of Microsoft Excel in addition to my data acquisition skills.

I found it extremely helpful to have a working understanding of the Antiproton Source. This knowledge helped me understand the Excitation Analysis, plus it aided in the integration of the data from all the magnets. Furthermore, his aid in my inventory was invaluable. Thanks to Steve Werkema for supplying me with the information for my Excitation Analysis. Thank you to Mrs. Eva Clark for bringing levity to an otherwise drab task and acting as my alarm clock in some times of need. Dr. Davenport showed me that there is more than just an inventory to talk about. Dianne Engram and the SIST Committee for providing the opportunity to earn a paycheck while in an academic pursuit. Jennifer Guyton, my fiancé, thank you for being there throughout all of my trials and hardships. Anton Smith and John Biddle, you are some cool kats, the summer was less boring that it could have been. Michelle Walker, Stacey Nordt, Kamonayi Mubenga, and Lola Ogunmefun, thank you for your support in my extracurricular activities. And finally Natalie Johnson for supporting my basketball habit.