Fermi National Accelerator Laboratory

FERMILAB-Conf-93/132

Reliability of the Fermilab Antiproton Source

E. Harms Jr.

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

May 1993

Presented at the *1993 Particle Accelerator Conference,* Washington, D.C., May 17-20, 1993

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

Disclaimer

Reliability of the Fermilab Antiproton Source

E. Harms, Jr.
Fermi National Accelerator Laboratory*
P. O. Box 500, Batavia, IL 60510 USA

Abstract

This paper reports on the reliability of the Fermilab Antiproton source since it began operation in 1985. Reliability of the complex as a whole as well as subsystem performance is summarized. Also discussed is the trending done to determine causes of significant machine downtime and actions taken to reduce the incidence of failure. Finally, results of a study to detect previously unidentified reliability limitations are presented.

I. INTRODUCTION

The Fermilab Antiproton source consists of two storage rings, the Debuncher and Accumulator, which operate at a nominal energy of 8 GeV, a production target station, and beam lines connecting the rings and the target station to each other as well as the Fermilab Booster and Main Ring. During the current Tevatron Collider run, the source has achieved an all-time peak stacking rate of 4.54×10^{10} pbars per hour and a record peak Accumulator intensity of 1.61×10^{12} antiprotons. Typically, 2.7×10^{7} antiprotons are produced and stacked in the Accumulator based on a flux of 1.8×10^{12} 120 GeV protons striking the production target every stacking cycle.

Since its first operation in 1985 the Antiproton source complex has provided antiprotons for three Tevatron Collider runs. During fixed target periods it has served the needs of E760 studying the spectroscopy of charmonium states produced by $p\bar{p}$ collisions in the Accumulator [1].

Table 1
FNAL Pbar Source Operations History
for Physics Runs

DATE	DURATION (WEEKS)	PURPOSE OF RUN
2 Feb., 1987 to 15 May, 1987	14	Tevatron Collider
4 July, 1988 to 4 June, 1989	48	Tevatron Collider
1 July, 1991 to 20 Jan., 1992	30	E760
4 May, 1992 to present	50 (to date)	Tevatron Collider

Table 1 lists the dates and duration of physics runs of the Pbar source. Data for this paper is limited to that gathered during these periods. The time between runs has been spent on machine improvement beam studies or shutdowns for system improvements and additions.

II. RELIABILITY

Reliability was studied in three ways: by means of recorded downtime, a Equipment Failure Report (EFR) system maintained by Pbar source personnel, and analyzing the frequency and reasons behind losses of stacks in the Accumulator.

A. Downtime

Machine downtime is recorded by an applications program resident on the Fermilab Accelerator controls consoles. Main Control Room operators log items that cause any program interruption. Every entry provides the identity of the device causing the downtime, the subsystem to which it belongs, the duration of the interruption, and detail of the problem. Off-line analysis capability is also provided. Table 2 summarizes recorded Pbar source downtime since 1 February, 1987.

The 1255.85 hours of recorded downtime is 7.6% of the total accelerator complex downtime during the period. The two major contributors of Antiproton source downtime are the antiproton production target station and beam transport line power supplies. Both deserve further mention.

Antiprotons produced by targeting 120 GeV protons are collected by the Lithium lens. Failures of this device account for 245 of the 300 recorded hours that the target station was not operational. There were eleven instances where repair or replacement of a lens/transformer assembly was necessitated by failures of the cooling water channels during the 1988-89 Collider run. This period was the worst in terms of lens problems. During those 48 weeks of operation an average of nearly 3 hours of target station downtime was accrued per week of source operation. An average of 1.5 hours per week is the norm for the run in progress. Thanks to improvements in lens/transformer design and manufacture, the lens problems of 1988-89 have not been repeated [2].

The second leading cause of target station down time is failures of the pulsed magnet that bends 8 GeV negatively charged particles into the AP2 line. Whereas five pulsed magnets failed between April 1987 and October of 1991, there has yet to be a

---

* Work supported by the United States Department of Energy under Contract No. DE-AC02-76CHO3000.

failure since a magnet of new design was installed in January 1992. The new magnet is a single-turn, water-cooled, radiation hard device.

Table 2
Summary of FNAL Pbar Source Downtime

System	**Hours of Downtime Accrued**	**Percentage of Pbar Total**
Vacuum systems	9.02	1.0
Beam line power supplies	276.52	22.0
Accumulator power supplies	95.43	7.5
Debuncher power supplies	122.13	9.7
Accumulator RF systems	90.21	7.2
Debuncher RF systems	38.29	3.0
Accumulator stochastic cooling systems	82.15	6.4
Debuncher stochastic cooling systems	25.41	2.0
Production target station	299.70	23.9
Diagnostics	13.25	1.1
Correction elements and supplies	3.15	0.3
Miscellaneous	168.51	13.4
Controls	32.08	2.5
Total	1255.85	100.0

The largest single contributor to beam line supply downtime both in terms of hours accumulated and number of occurrences was the original power supply for the pulsed extraction septum (Lambertson) magnets from the Main Ring to the production target. This device accounted for over a quarter of the total for this category. In the summer of 1988 the power supply was replaced by that of a different design which to date has accumulated only 15.8 hours of downtime.

More recently, overheating magnets in the AP2 line connecting the target station to the Debuncher have contributed approximately 30 hours of downtime scattered over more than 90 such incidents. The frequency of such occurrences has been minimized in part by ramping those magnet strings most prone to overheating rather than running them DC. Plans are being formulated to mitigate such problems in the future by flushing out the entire Pbar source water system and adding filtering during the upcoming scheduled shut down.

B. Equipment Failure Reports

Another reliability indicator is Equipment Failure Reports (EFR's). EFR's are written reports filled out by technicians making repairs to or replacing faulty components. The Pbar EFR system in its current configuration has been in place since May 1990 [3]. EFR's are filled out only on components which fail during normal operating periods; repairs and replacements made during extended scheduled maintenance periods are not so documented. Figure 1 is a summary of EFR data.

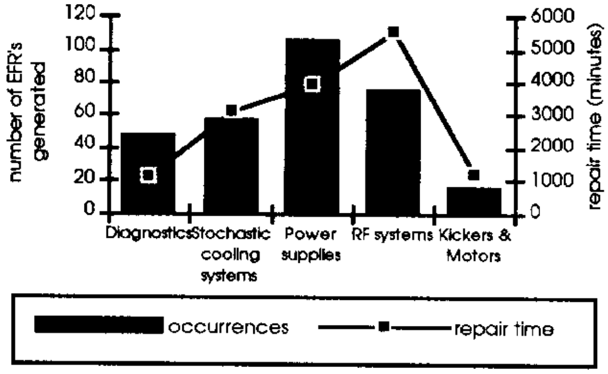

Figure 1
Summary of FNAL Pbar source
Equipment Failure Reports

In general, three classes of power supplies are used to excite Pbar source rings and beam line magnets: those with output less than 1 kW for dipole correctors, those with output in the 1 to 80 kW range for beam transport elements and ring quadrupoles and sextupoles, and those with output more than 1 MW for ring dipoles and major beam line dipole strings. The low power supplies contribute the second leading number of incidents, yet the least amount of repair time because these supplies are more often replaced rather than repaired in the field. The middle class has the most failures, though problems usually lie with instrumentation or metering rather than actual internal problems. Devices comprising the third class, while having the fewest failures, generally take the longest time to repair. A fourth class of devices, shunts for fine control of individual elements in series strings of dipoles or quadrupoles, have their share of failures as well.

The Accumulator and Debuncher each contains three radiofrequency systems. DRF1, the Debuncher 53 MHz bunch rotation and debunching system, has generated the greatest number of EFR's in the RF system category. This is primarily due to the larger number of components in this system than in the five others. DRF1 is comprised of eight cavities generating up to 1 MV each while the five other RF systems combined total six cavities generating substantially less voltage with a lower duty factor.

Traveling Wave Tube (TWT) power supplies dominate the Stochastic Cooling generated EFR's. Seventy-five such supplies drive the final stage of amplification of the stochastic cooling kickers for the nine cooling system used in the Antiproton source. No single mode of failure dominates [4].

Microprocessor-based scanners for the beam line Secondary Emission Monitor (SEM) grids are the most troublesome diagnostics component. Many of these devices are installed in the beam line enclosures and are sensitive to the radiation found in those areas. Some scanners, specifically those in the 120 GeV line from the Main Ring to the target station and near the major bends in the injection and extraction lines, have been moved to the quieter environment of adjacent service buildings. The rate of failure of devices so moved has dropped significantly. Additional scanners will be moved out of the tunnels as resources permit.

C. Lost Stacks

A third measure of reliability is the frequency of loss of particles stored in the Accumulator, known colloquially as 'dumping a stack'. Figure 2 summarizes the frequency and reasons for dumped stacks over the history of the Pbar source. On average, a stack is dumped once per two weeks of operation. The longest sustained stack was 39.4 days achieved during November and December of 1988.

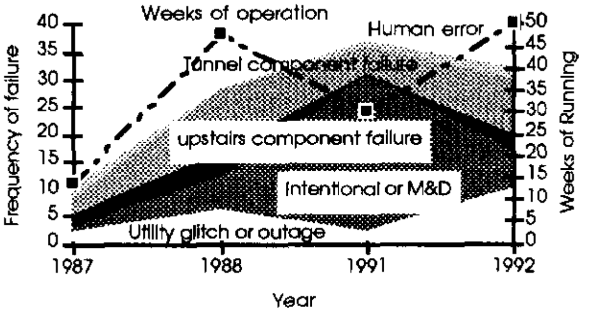

Figure 2
Summary of Dumped Stacks 1987 to present

Dumped stack data from 1991 is unique in that the Accumulator was used as an experimental area for E760. A typical week consisted of 42 hours of antiproton stacking, 92 hours of data taking and time for experimental set up and scattered downtime. Since most stores required decelerating the antiproton beam to an energy less than the accumulation energy of 8 GeV, what was left of the stack at the end of a store was dumped, an access made if necessary, then the Accumulator turned back on for antiproton stacking. Fewer component failures were encountered due to less stacking time per week compared to Collider operation and because unneeded loads were turned off once set up for a store was begun.

Over the history of the Pbar source, most dumped stacks have been due to failure of a component in the Debuncher/Accumulator tunnel. Failure of a pulsed septum or kicker magnet module was the culprit in thirteen of the twenty-nine such cases.

Utility glitches or outages have contributed twenty instances. Most such losses are traceable to glitches on the transmission grid of the electricity utility supplying Fermilab.

Only a handful of dumped stacks can be attributed to human error.

III. SUMMARY

The Fermilab Antiproton source has been in operation for nearly seven years. As a whole, it has proved to be a reasonably reliable complex. The best measure of stand-alone up time has come during periods of running for E760 when 80% of the time was accounted for either by antiproton stacking or data taking. Such a measurement for Collider operation is complicated by set up time for antiproton transfers to the Main Ring/Tevatron and a generally greater reliance on the other machines in the Fermilab complex. There has been an average of 91 stacking hours per week during the present Collider run which compares favorably with past operation.

An analysis of the data has yielded no surprises as far as uncovering previously undetected reliability limitations.

Known unreliable components are replaced or upgraded as resources permit. Notable changes to date include replacement of the power supply energizing the pulsed extraction septa from the Main Ring to the target station, improved design and manufacture of Lithium lenses, a target station pulsed magnet of better design, improvements to the design of pulsed magnetic septum magnets, more reliable capacitors in the kicker magnet modules, replacement of RG-220 coaxial cable for the kicker magnet systems [5], and relocation of selected SEM grid scanners from the beam enclosures to service buildings.

IV. ACKNOWLEDGMENTS

The author thanks past and present members of the Fermilab Accelerator Operations department for providing down time information and Bernard Wisner of the Fermilab Pbar source department for EFR summaries.

V. REFERENCES

[1] S. Werkema, private communication
[2] S. O'Day, private communication
[3] J. Marriner, Fermilab Pbar source internal memo
[4] W. Mueller, private communication
[5] J. Petter, "Improved High Voltage Coax for Antiproton Source Kicker Pulse Forming Networks and Pulse Transmission", *Proceedings of the 1989 IEEE Particle Accelerator Conference*, Vol. 3, pp. 1951-1953.