ACCELERATOR RELIABILITY DATABASE

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Abstract

Accelerator beam trips have been identified as a significant issue in the development of high power accelerator driven systems envisioned for transmutation of waste, energy amplifiers, etc. where the accelerator must work in conjunction with a subcritical reactor. In order to enable the design of these systems with the high reliability required, a reliability database is being assembled. This paper provides preliminary results which may be of use in conceptual design considerations.

1 INTRODUCTION

The idea of the database effort originated with the International Fusion Materials Irradiation Facility (IFMIF) accelerator reliability analyses in 1995 when it was realized that information available at the time to support these analyses was very limited [1]. A reliability survey of operating accelerator facilities has been started in the summer of 1997. Data was collected from literature, personal communications via phone and email with staff members and site visits at a number of accelerator facilities, including: ISIS, CERN, DESY, LANSCE, TJNAF, Fermilab, etc. While the completion of the accelerator reliability database is still far ahead, the LANSCE data set was analyzed in early 1998 and the details of this effort are described in [2,3,4]. In [5], the data was analyzed as a random process. Here, we present additional results believed to be of potential utility in Accelerator Driven System (ADS) system planning. Since the subcritical reactor in ADS is very sensitive to beam trips, it is important to know the distributions of the beam trip down times and the times between down time events. Although these statistics will be different for each specific design, the scale of the LANSCE linac is believed to be representative of a linac for ADS (it is noted, however, that the Proton Storage Ring is included here).

2 DATA

Table I summarizes the statistics for all the data points available, which consist of cycles 71 through 76 from 7/10/96 to 7/27/97 (some data had to be censored: primarily to eliminate a number of overlapping down time events, but it should be noted that the sampling of data at one minute intervals represents another censoring mechanism). Each cycle is a separate campaign separated from the others by a built-in production stop for maintenance. Additional maintenance budget is included in the schedule and exercised during each cycle as listed.

Detailed data is provided in the figures on the next page. Figure 1 shows the cumulative number of down time events as a function of calendar time. Figure 2 shows the same data as a function of the cumulative uptime. Figure 3 shows the histogram of the Times Between Events (TBE) and Figure 4 shows the histogram of the Down Times (DT). Since the DT histogram is highly skewed to the left, Figure 5 shows the DT histogram with an expanded horizontal axis to show more details. This distribution is typical of the down times. Most of the down times are very short (75% below 15 min.), but there are usually a few outliers (here, 58h 54 min. due to a magnet power supply).

Figure 6 illustrates an attempted fit of the TBE's with an exponential distribution. Clearly, the fit is not so good. However, a Weibull distribution with characteristic life of 6 hours and shape factor of 0.67, shown in Figure 7 fits the data remarkably well. When plotted on the log-linear paper in Figure 8, one can see that the Weibull fit slightly underpredicts the probability of the short TBE's but it is still very satisfactory.

Table I. LANSCE Summary of Operational Data

Cycle#	71	72	73	74	75	76	Total
Run Start Time	7/10/96 8:00	8/30/96 2:10	10/29/96 20:00	3/7/97 8:00	4/23/97 8:00	6/18/97 8:00	
Run End Time	8/24/96 8:00	10/21/96 7:00	11/28/96 20:00	4/21/97 8:00	6/16/97 8:00	7/27/97 8:00	
Calendar Time (h:min)	1080:00	1252:50	720:00	1080:00	1296:00	936:00	6364:50
Built in Stops (h:min)	115:07	191:00	66:00	84:11	38:50	44:41	539:49
Cum Uptime (h:min)	811:14	1042:23	626:47	952:01	1129:33	825:54	5387:52
Cum Downtime (h:min)	153:39	19:27	27:13	43:48	127:37	65:25	437:09
Availability	0.84	0.98	0.96	0.96	0.90	0.93	0.93
Total Number of Down Time Events	135	140	75	97	175	109	731
Mean Time Between Events (h:min)	5:56	7:14	8:16	9:48	6:21	6:44	7:23
Mean Down Time (h:min)	1:08	0:08	0:21	0:27	0:43	0:36	0:34

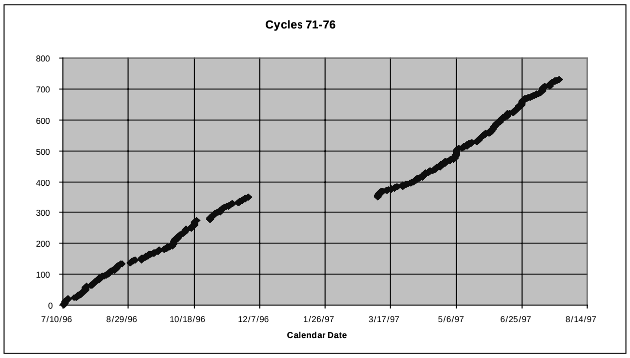

Figure 1. Cumulative Number of Down Time Events vs. Calendar Time

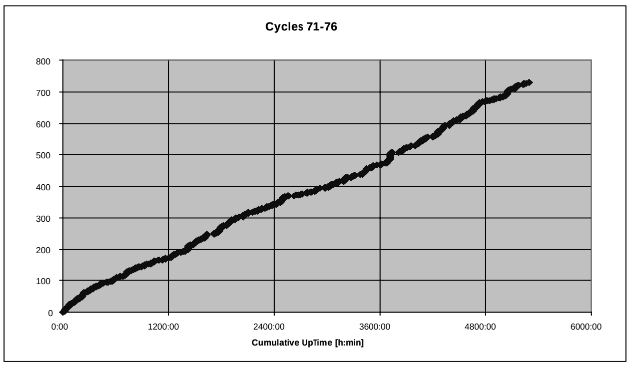

Figure 2. Cumulative Number of Down Time Events vs. Cumulative Uptime

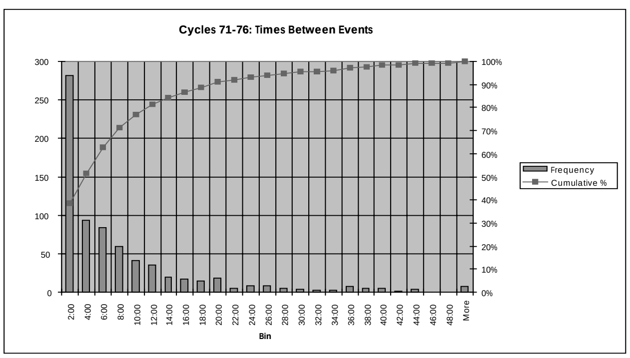

Figure 3. Histogram of Times Between Events

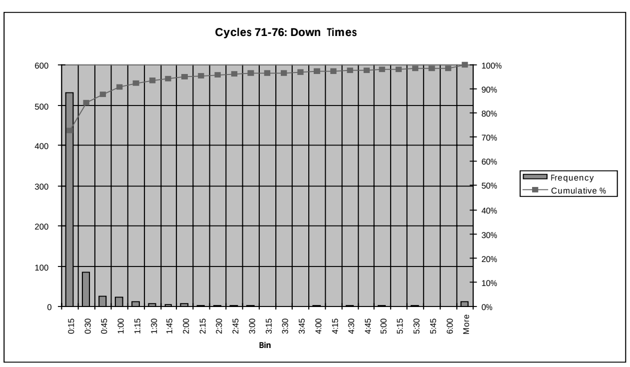

Figure 4. Histogram of Down Times

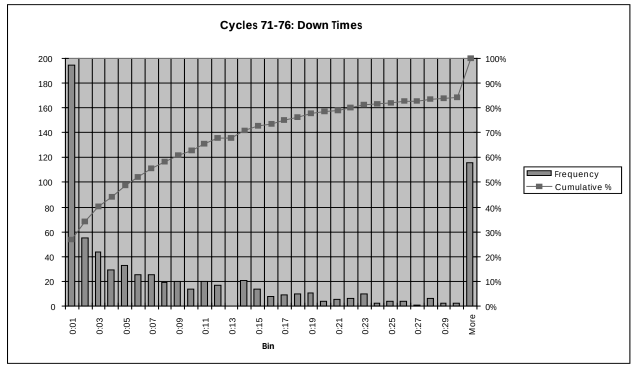

Figure 5. Histogram of Down Times (Expanded)

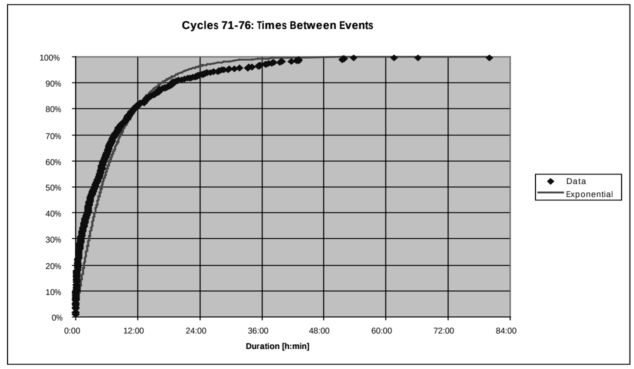

Figure 6. Exponential Fit of Times Between Events Data

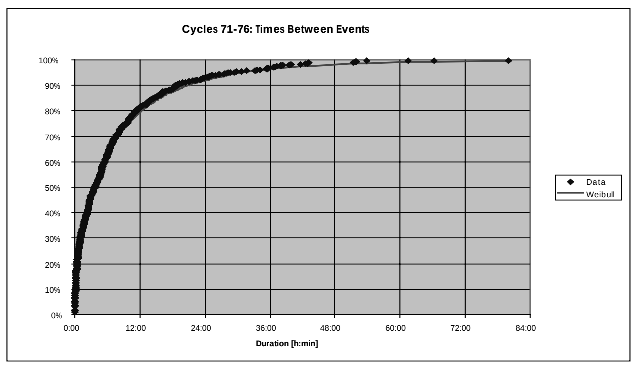

Figure 7. Weibull Fit of Times Between Events Data

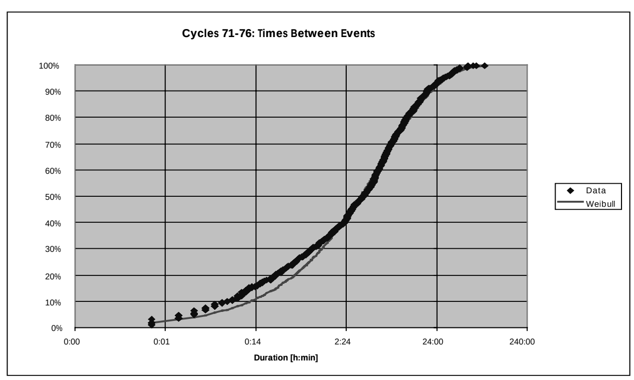

Figure 8. Weibull Fit of Times Between Events Data (Expanded)

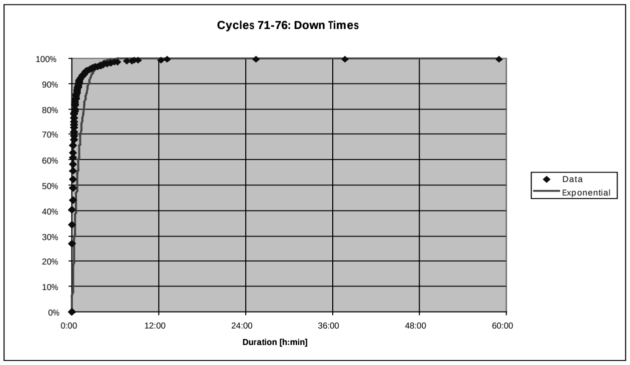

Figure 9. Exponential Fit of Down Times Data

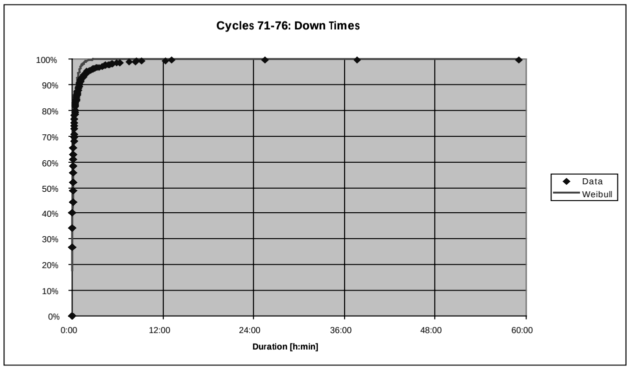

Figure 10. Weibull Fit of Down Times Data

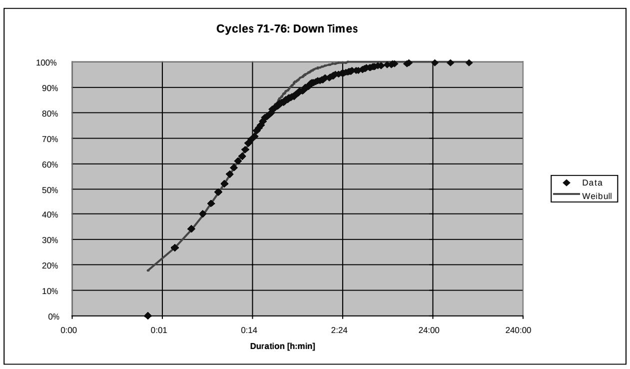

Figure 11. Weibull Fit of Down Times Data (Expanded)

The DT's cannot be fitted so easily. Figure 9 shows an unsuccessful fit of the DT data with an exponential distribution. A Weibull curve with characteristic life of 11 minutes and shape factor 0.7 shown in Figure 10 fits the data very well in the short duration range. This can be seen more clearly in Figure 11 with the horizontal axis stretched out via the log scale. Figure 11 shows also that this Weibull distribution overshoots the data in the range of the long down times. However, 75% of the data falls below 15 min.

3.0 CONCLUSIONS

The capability to predict the reliability characteristics of the linac driver in the future ADS system is important for many reasons. Primarily, the beam trips will be a significant neutron flux driver in the subcritical reactor. In addition, prediction of beam trip probabilities is needed for maintenance scheduling, advance spare parts procurement, and general reliability and availability design. While each particular design will require a separate reliability analysis, the data presented in this paper may be useful for preliminary planning. For the long term, the first step in assuring a satisfactory reliability performance of complex repairable systems such as accelerator facilities will have to be a thorough analysis of all existing operations data.

REFERENCES

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[3] C. M. Piaszczyk, "Operational Experience at Existing Accelerator Facilities", NEA Workshop on Utilization and Reliability of High Power Accelerators, Mito, Japan, October 1998

[4] C. M. Piaszczyk and M. Rennich, "Reliability Survey of Accelerator Facilities", Maintenance and Reliability Conference Proceedings, May 12-14, 1998, Knoxville, Tennessee

[5] C. M. Piaszczyk, "Understanding Accelerator Reliability", Linac '98, August, 1998, Chicago, Illinois