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LAMPF Reliability History And Program

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Abstract. Many years of service of the 800-MeV LAMPF H^+/H^- linac offers the opportunity to evaluate the long-term reliability characteristics of a high-power machine, which with up to 800-kW beam power available is as close to an ADTT machine as exists in the world today. Records from the last 15 years of operation were analyzed for trends and areas of deteriorating reliability or disproportionate downtime and used to support engineering judgment on facility refurbishment to regain beam availability. This round of analysis has helped define a further level of detail and automation to be implemented in availability recording. Interesting features which emerge from the history include a clear measurement of the lower availability in the first operating cycle following extended maintenance periods, and a consistent picture of the highest availability to be expected in extended operating periods with the facility as used and maintained. The results provide a starting point for informed discussion of reliability goals.

RELIABILITY HISTORY

Over the two decades of LAMPF operation, beam availability was logged automatically by the control computer and downtime was logged manually for about half-a-dozen major beam delivery systems in a fairly consistent manner. Readily-available records cover the last 15 years of operation and include downtime by major subsystem accumulated for 6-7 week operating cycles typically with 3-4 cycles per year, or 2000-4000 h/y.

Fig. 1 shows H^+ beam availability since 1979. The average availability is the horizontal line labelled *all*; also shown is the average availability for the *first* run cycle in each block and the *best* in each block. Availability appears to trend downwards through '92 and to recover in '93. The data refers to the portions of the system used for H^+ delivery, as shown in Fig. 2.

Fig. 1. H^+ Availability since 1979; points from contiguous run cycles connected by lines.

Fig. 2. LAMPF schematic – 3 injectors, linac, 3 main beam delivery areas.

Fig. 3. Downtime by major systems.

downtime were established early in the facility lifetime and lack some of the detail one now sees as useful. For example, the vacuum system downtime includes the considerable downtimes experienced in the high-intensity target area. A more complete system would record downtime by major area as in Fig. 2 and by type of system (vacuum, magnets,...).

Fig. 3 shows the system downtimes as a fraction of scheduled time averaged over the last five years, a period of nominally steady operation well past the Proton Storage Ring commissioning period. The injector downtime is shown averaged over the 3 injectors, to reflect average unavailability per beam, although the polarized and high-intensity H- injectors accounted for most of the time down. The equipment categories for logging

RF SYSTEM RELIABILITY

The 201rf system, which includes three ~2 MW power amplifier stages, had the highest unavailability of the major subsystems as they were defined. The DTL as a system would have had even larger downtime, because some of the downtime listed under distributed systems, such as vacuum, occurred in the DTL.

Fig. 4. 201rf downtime since 1979.

Fig. 4 shows the 201rf downtime since 1979. There appears to be a trend towards poorer reliability, with some dramatic swings. Of course there is an element of randomness in some of the fluctuations, and although some system improvements were made in '93, during most of the operating period no critical spares were available and the potential for extensive downtime was high.

Fig. 5. 805rf downtime since 1979.

As a "control variable," 805rf downtime is shown in Fig. 5. There is no obvious correlation with time or 201rf performance, and system reliability remains high and relatively uniform. The system includes 44 klystrons.

One of the few measurable parameters expected to correlate with 201rf performance is duty factor (power dissipation). To examine this, 201rf duty factor and 201rf downtime are plotted in Fig. 6. The rf duty factor data was recreated partly from old log books and other records. Both the duty factor and the downtime are averages over cycle blocks (typically 2-3 run cycles per block).

Instead of showing a distinct upward-breaking curve, the data are scattered with only a weak correlation. Among factors reducing the expected correlation is the deliberate reduction in duty factor during episodes of poor rf reliability. This illustrates the point that although simple tracking and trending are valuable tools, they must be used together with engineering analysis to establish root cause and proper corrective action.

Fig. 6. 201rf downtime vs. duty factor.

RELIABILITY PROGRAM

In response to increasing 201rf downtime, a modest upgrade effort was mounted in the last few years, and the rf stands were run very carefully in 1993. One significant improvement was a considerable increase in instrumentation. Instruments added included a calorimetric measure of Power Amplifier tube anode dissipation, to remove any doubt about this value in operation and how close it was to the 300-kW rated maximum, and to allow an accurate record to be accumulated on tube dissipation vs lifetime. Another monitoring capability added was the ability to capture the PA modulator tube current oscilloscope traces when hv power supply crowbars occurred; this allowed significant problems to be uncovered. This kind of capability tends to be very inexpensive compared to the value of the equipment concerned, the value of the production time saved, and the cost of the maintenance effort required during poor operation.

A rather scattered set of conclusions might be drawn from the 201rf reliability history, one being that a small capital investment skillfully applied can have a significant impact on performance. This suggests another conclusion, that typical accelerator systems may not have easily-characterized (or time-invariant) reliability. Finally, it appears that at least 13% rf duty factor (10% beam duty factor) can be run in this machine with average reliability under some conditions

(presumably these include modest peak power demand, e.g., moderate beam loading, and good maintenance).

The 201rf reliability program will continue over the next several years in a catch-up mode. Improvements include a more detailed level of computer logging of performance, power supply modernization, improved modularity, and replacement of vacuum tube equipment by solid-state equipment as the state of the art allows. Unfortunately, redundancy in the high-power rf systems is expensive to implement.

LESSONS LEARNED

Lessons learned from our reliability experience include the usefulness of continuing performance oversight with measures, records, and analysis at the proper level of depth; the importance of a good operating team where management, engineering, and technician levels work together to ensure continuing high standards of system knowledge; and the payoff of sound design with adequate reserve and maintainability engineered in. In order to keep a facility in top operating shape, one should plan a continuing program of refurbishment and modernization perhaps at the level of 2-5% of the operating budget every year.

With the planned improvements and continuing maintenance, long-term linac availability in the range of 90% with beam power at the 1-MW level suitable for ADTT applications appears to be feasible.

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