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THE LAMPF 805 MHz RF SYSTEM*

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Summary

The LAMPF 805 MHz RF system was available 97.7% of the scheduled beam time (2,432 h) during experiment cycles 25 and 26, January to June 1980.[1] The tube lifetimes, operation, maintenance, and processing which lead to this reliability are discussed. The LPT-44 triode, used as a switchtube in the modulator has a mean life > 16,000 h. The 805 MHz L-5120A klystron has a mean life > 10,000 h and the 805 MHz klystron VA-862A apparently will have a mean life > 50,000 h. Tube life data is plotted. Fault and failure modes are discussed and tabulated.

Introduction

The Clinton P. Anderson Meson Physics Facility (LAMPF) in Los Alamos, New Mexico has been reliably accelerating a 10 mA (peak) proton beam at 9% duty factor. The 805 MHz rf system, with 44 1.25 Mw klystrons, supplies the power to accelerate the beam from 100 MeV to 800 MeV. The facility operates about 5,000 h per year plus another 1,000 h per year at low duty factor for system development, preventive maintenance, etc. More than 2,000,000 socket hours have accumulated on the rf system.

The klystron amplifier unit consists of a modulating anode klystron and its focus solenoid mounted on a tank, with a floating deck modulator and switchtube in oil in the tank.[2] The klystron amplifier units are clustered, six or seven to a building, in the seven 805 MHz sector buildings. There is an 86 kV dc supply for each sector building. There are nine spare klystron amplifier units in the sector buildings, plus two being repaired or processed at the Electronics Test Laboratory (ETL). One of the 3,200 kg amplifier units can be replaced in less than two hours.

The switchtube used is the Machlett LPT-44 triode. The amplifiers used are the Litton L-5120A and the Varian VA-862A klystrons. The two klystrons are similar in gain and efficiency, use the same solenoid and modulator, and deliver the same output power. The two klystrons use different sockets and filament voltages. The L-5120A requires an air stream to cool its alumina window; the beryllia window of the VA-862A is water cooled. The L-5120A is used in one sector building; the VA-862A is used in six sector buildings.

Reliability

To achieve a 97.7% availability for the 805 MHz rf system, the mean time to fault (MTTF) must be long, and the meantime to repair or replace must be short. A fault is a problem that would cause loss of beam time. The most common fault is an arc in the klystron or modulator. The system is protected by the high voltage crow bar, which turns off the high voltage and dumps the stored energy. Normally there is no damage and the computer resets the interlock and has the machine running in ten minutes. The average crow bar[3] rate for the 805 MHz rf system is 0.6 (or six minutes lost) per day.

The next most common problem is a switchtube fault. The MTTF for the LPT-44 switchtube on the accelerator is 3,400 h, for a switchtube fault rate of 0.3 per day. It takes about 45 minutes to replace a switchtube and turn the system on, however, the replacement of many of the faulty switchtubes can be delayed until a maintenance period. This results in an average beam loss of less than 30 minutes to replace a switchtube (nine minutes per day).

The klystrons are charged with all the faults of the klystron amplifier unit not attributed to the switchtube. The MTTF of the L-5120A over the last eight years is 5,200 h. With six L-5120A klystrons on line and a 120 minute replacement time, their fault rate has been 0.03 (or three minutes lost) per day.

The VA-862A klystron has a MTTF of 30,000 h. With 38 of these klystrons used on the accelerator and a 120 minute replacement time, their fault rate has been 0.03 (or 4 minutes lost) per day. Eight VA-862A klystrons have remained in place since the accelerator was built. The klystron is driven by a 40 W solid state amplifier that is almost trouble free. Trouble shooting, replacing and adjusting phase and amplitude controls, power supplies, and other equipment ancillary to the klystron amplifier units result in another 10 minutes lost per day.

Tube Life

After faulting on the accelerator, the tubes are repaired or processed and tested at ETL. Table I is a list of the common fault modes and their relative frequency for each tube type. Table II is a similar table of the failure modes. Most fault problems can be remedied by processig or modulator repair. Failures are the end of tube life problems that result in switchtubes being scrapped or klystrons being rebuilt.

Table I.
Fault Modes, (No.), %

Tube Type	LPT-44	L-5120A	VA-862A
On Line Faults	(371)	(44)	(15)
Poor Vacuum	0	13	9
Water Leak	0	7	25
Cathode Fault	9	7	5
Internal Arcing	3	27	20
System Problem	12	33	41
Operator Error	1	7	0
Leakage Current	75	7	0

Table II.
Failure Modes, (No.), %

Tube Type	LPT-44	L-5120A	VA-862A
All Failures	(96)	(26)	(21)
Poor Vacuum	3	15	32
Water Leak	0	4	14
Cathode Failure	54	8	18
Internal Arcing	3	58	27
System Problem	3	11	5
Operator Error	4	4	5
Leakage Current	30	0	0

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Poor vacuum from a very small or virtual leak often shows as a pressure burst when the cathode heater is turned on. Pressure burst problems are minimized by turning the cathode heater on early or leaving the cathode heater on at low power on spare klystrons. Klystrons with larger vacuum leaks due to high voltage (HV) punctures and braze joint leaks are rebuilt.

Water leaking into the modulator causes HV problems and occasionally the loss of a klystron due to HV puncture of a ceramic. The normal source of water is a leaking quick disconnect, but other sources have been porous castings, leaking braze joints and pipe fittings, and leaking overhead water pipes. Water problems are minimized by careful alignment and the use of new gaskets on the quick disconnects.

Most of the switchtubes with cathode problems are approaching a normal cathode end of life, but a few have broken filaments. Broken filaments are minimized by careful handling and foam lined storage boxes. In klystrons, the cathode problems have been caused by poor vacuum, internal arcs, and bad electrical connections.

Most of the arcing in klystrons has been from the modulating anode to the body. The arcing is minimized by running the klystron at or just above the cathode current emission knee.

System problems may be failed structural insulators, components damaged by arcs, poor electrical connections, etc. Polyethylene insulation has swelled in the oil and forced wire conductors of their sockets.

Considering the complexity of LAMPF and the number of years of operation, there have been very few operator errors.

Most leakage current in klystrons comes from ceramics dirtied by internal arcs. Leakage current in switchtubes is normally due to microscopic whiskers or visible whiskers (platinum cladding peeling from the grid). HV[4] processing will normally return these tubes to service.

Figures 1, 2, and 3 show the cumulative frequency of failure of the tubes used in the 805 MHz system. Ninety-six LPT-44 switchtubes have failed. The straight line to the last failed tube at 30,000 h in Figure 1 indicates that the failure rate is almost constant for any age tube. There are eight good tubes between the last fault at 30,000 h and 41,000 h, the oldest running LPT-44. The average LPT-44 goes through a HV-process run-test six times before final end of life. A tube passing the run test has the same MTTF as a new tube. Integration of the curve indicates the average life of the LPT-44 triode will be greater than 16,000 h.

Twenty-six L-5120A klystrons have failed. The curve reflects a high early failure rate due to cathode and HV problems. Klystrons which fail are rebuilt at ETL. The oldest rebuilt L-5120A has 39,000 h. The oldest original L-5120A has 40,000 h. The average life of the L-5120A even with the early failure problem will be greater than 10,000 h.

Twenty-one VA-862A klystrons have failed. The straight line to the last failure point at 30,000 h again indicates a constant failure rate and random failure modes. There are 29 good tubes scattered above the last failure point, with the oldest at 58,000 h. The average life of the VA-862A will be greater than 50,000 h. The average life and MTTF of

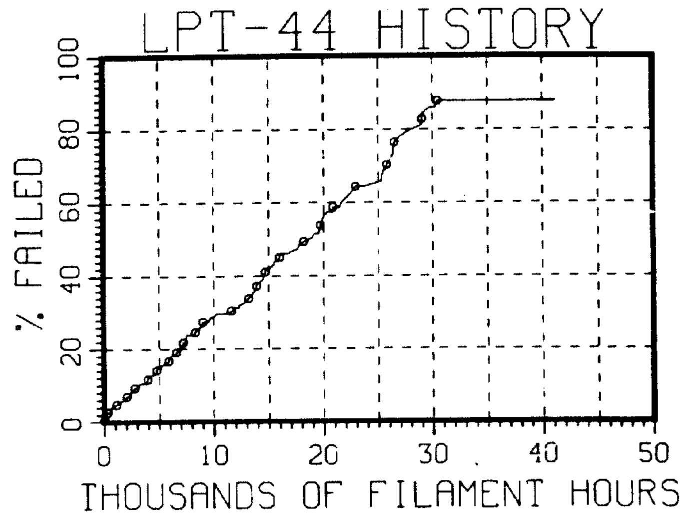

Fig. 1
LPT-44

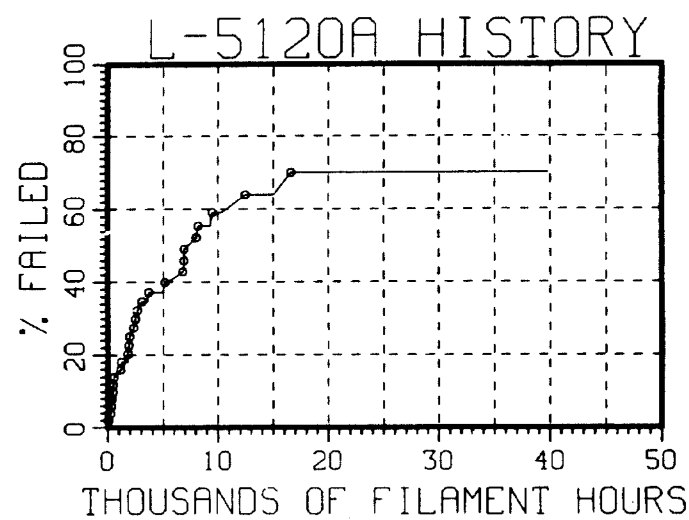

Fig. 2
L-5120A

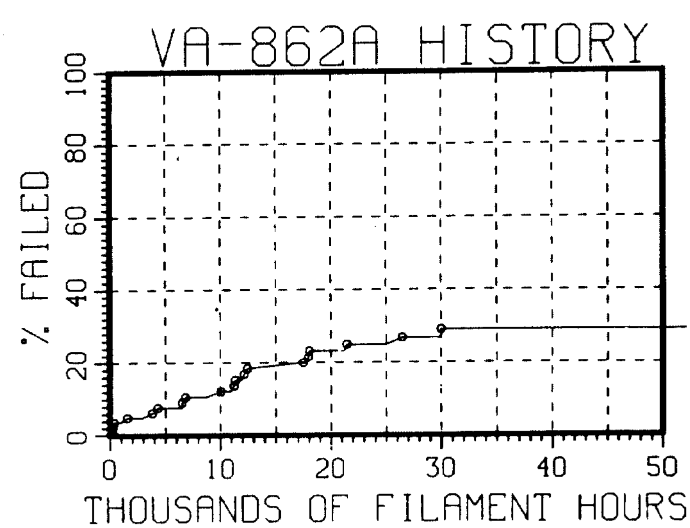

Fig. 3
VA-862A

all the tubes[5] increases with experience and improved handling and processing procedures.

Operations and Maintenance

The accelerator normally operates continuously for two weeks and then is shut down 16 h for maintenance. The operations group controls and monitors the accelerator with the aid of a computer. A maintenance group is on hand during the day or on call at any time. The maintenance period is used for tests, adjustments, and repairs that could wait until the end of the operating period. Major changes are only made when long maintenance periods are scheduled.

A complete set of spares is maintained in every sector building. Spare klystron amplifiers have power on their ion pump and low power on the cathode heater, to minimize replacement turn on time. The spare klystron amplifier units are returned to ETL for processing after 1.5 years. Nine spare klystrons are maintained in the seven sector buildings so there is always time for proper checkout and processing.

References

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