THE LAMPF KLYSTRON REPAIR FACILITY*

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Abstract

Major and minor repairs on the 1-1/4 MW, 805 MHz LAMPF klystrons are being performed in-house. This paper discusses the repair facility and the processes and procedures used to effect these repairs. The minor repairs usually consist of cleaning the outside of a ceramic insulator and hi-potting the electron gun. The klystron is cut open for a major repair; one or more parts are repaired or replaced, the cathode is cleaned and recoated and the tube is reassembled, evacuated, baked out and reprocessed. Several of the more critical procedures such as the vacuum bakeout and cathode cleaning, coating and activation are discussed in some detail. The observed failure rates and mechanisms are presented for the klystrons and for several other high-power tubes which are used at LAMPF.

Some of the hi-potting procedures and equipment have been used to reprocess the modified ML-8495 switching triodes which are used in the klystron modulators. Several of these triodes have been reprocessed at LASL to restore their original high voltage capabilities. The hi-potting procedures for the triodes and klystrons are presented. Several triodes have exhibited excessive grid emission, and a procedure to heat the grid has been effective in these cases.

I. INTRODUCTION

Forty-four 1-1/4 MW, 805-MHz klystrons are used in the LAMPF rf system. These klystrons, their focus electromagnets and a floating-deck modulator are the major electrical components in the rf amplifier modules. One amplifier module is shown in Fig. 1. In the accelerator buildings only two items of the amplifier module are serviced in place, the switch tube and a bias board for the switch tube. When more extensive maintenance is necessary, the entire module is replaced by a spare. This replacement process takes about two hours. The module to be repaired is moved, via forklift, approximately a half mile to the Electronics Test Laboratory Building (ETLB) for further testing and repair. The procedures and equipment which are used to repair the klystrons and the associated switching triodes are discussed in this paper.

II. MINOR KLYSTRON REPAIRS

Minor klystron repairs can be performed without disturbing the vacuum integrity of the klystron. Generally, they are high-voltage modulator arcing and rf output window arcing. In the first case, the klystron is removed from its magnet and the modulator is inspected for water, since this is the more common cause of modulator arcing. Any water is removed and the transformer oil is tested for dielectric strength and reprocessed if necessary. The external surfaces of the cathode and mod-anode insulators are inspected and cleaned. The electron gun is then hi-potted to 120 kV from mod-anode to body and 100 kV from cathode to mod-anode. The filaments are cold during the hi-potting and the operating polarity of the fields is used. The maximum current is held to 2 or 3 mA during the hi-potting process. The hi-pot supply is a commercial unit with a 0-10 mA output capability. No external resistors or capacitors are used. Next, the klystron is operated at full rf output for 100 h at the ETLB. After this test, the klystron is again ready for service.

The rf output window arcing is generally on the air side and the output windows are cleaned by gently grit blasting with 320 mesh alumina. The klystron is then rf tested into both a flat load and a 1.5:1 mismatch. The klystron is returned to service after these tests.

III. MAJOR KLYSTRON REPAIRS

The vacuum envelope is opened for a major repair; one or more parts are repaired and replaced,

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the cathode is cleaned and recoated, and the tube is reassembled, evacuated and baked out. The major equipment requirements for these repairs are the vacuum bakeout oven, a vacuum firing station, brazing and welding facilities and dc and rf test equipment. The bakeout oven used at LASL has a heated zone 4 ft square by 12 ft high and it has 20 kW electrical input. The vacuum system consists of a 4 in. oil diffusion pump with a liquid nitrogen cold trap. The vacuum bakeout oven is the largest piece of equipment which had to be made for the repair facility.

The LAMPF klystrons (Types VA-862-A and L-5120) were both designed with ease of rebuilding in mind. Figure 2 is a simplified drawing of the electron gun assembly which shows the four kovar-welded joints which are used to assemble the gun. When the four seals are opened by grinding away the welded joints, the gun is disassembled into four components; the two ceramic insulators, the modulating anode and the cathode/focus electrode assembly. Any arc marks on the insulators are removed by grit blasting. The mod-anode and ceramics are then chemically cleaned. The old cathode coating material is removed by boiling the cathode assembly in distilled water. Weak acetic acid (3 to 5%) is used to loosen any stubborn areas of cathode material. Next the cathode assembly is hydrogen fired at 1100°C and then vacuum fired for 24 h with 10% over-voltage applied to the heater. After the vacuum firing, a commercial cathode mixture is applied by brushing and spraying to the nickel cathode. The work schedule is arranged so that the klystron is assembled, leak checked and evacuated on the day the cathode is coated.

The bakeout schedule calls for a maximum temperature rise or fall of 50°C/h followed by a 36 h bakeout at 400°C. When the klystron is cool, the cathode is activated by gradually raising the heater voltage while the vacuum is held to less than 2×10^{-5} torr. The nominal heater voltage for the VA-862-A is 11 V and conversion occurs at about 10 V. After conversion, the heater is operated for an hour each at 11 and 12 V and then flashed for an hour at 17 V. The heater voltage is reduced to 15 V for 8 h and then to 11 V at which time the gun perveance is checked. If this is good, the tube is pinched off, dressed, water tested, and then rf tested.

IV. OBSERVED FAILURES AND RATES

There were 5 failures in the 50 VA-862-A klystrons which have been operated to date in over 106,000 filament hours and 80,000 plate hours of operation. Several failures have occured in the L-5120 klystrons but all of these have been early failures which were repaired by the manufacturer under warranty. There is not sufficient life data on the L-5120's to be included in this paper. The five VA-862-A failures are listed in Table I, with the probable cause and age of each klystron.

The cracked mod-anode insulator is the only failure with more than one occurrence. In both cases, water was found in the modulator oil when the klystron was removed. The klystrons are now hydrostatically tested for water leaks whenever their water courses are altered or repaired.

One LPT-44 triode is used in the floating-deck modulator for each klystron. The LPT-44 is a 100 kV version of the ML-8495 triode. These have accumulated over 116,000 filament hours and 86,000 plate hours with two out-of-warranty failures. These were a filament-to-grid short and an open filament.

The cumulative failure probability for the triodes and klystrons is shown in Fig. 3. The respective life expectancies are 7,000 and 6,350 filament hours.

V. GRID PROCESSING

Ten LPT-44 triodes with an average life of 2,600 h developed grid emission which, if unchecked, could have resulted in an xray hazard from the modulators as well as excessive anode dissipation. The secondary emission from the grid is reduced by electron heating the grid on half of each cycle of the line voltage and measuring the grid-emission current during the other half of the cycle. A 1/2 h of grid bombardment, followed by hi-potting the triode for 1 h is adequate to reduce the grid emission by more than an order of magnitude. Nine of the triodes which have been subject to this treatment are now back in service; the tenth one developed a grid-cathode short in the reprocessing.

VI. SUMMARY

One high-power klystron has been repaired at the LAMPF repair facility. It passed all the acceptance tests which are applied to new klystrons and ran for 247 h at ETLB. An arc in the modulator tank subsequently cracked the mod-anode ceramic when this klystron was used in the accelerator. This arc was due to water leaking into the modulator oil.

Ten switching triodes which developed excessive grid emission were reprocessed by heating the grid and hi-potting. Nine of these triodes were repaired by this process and are now back in service.

The observed life expectancy for the klystron is about 6,350 filament hours. This implies that more than half of the klystrons will have to be repaired each year. The life of the triodes is about 7,000 h but grid processing is often required before 3,000 h.

ACKNOWLEDGMENTS

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TABLE I

VA-862-A FAILURES

S/N	Mechanism	Probable Cause	Filament Hours
103	Vacuum leak	Internal braze joint opened	6821
102	Cannot take high voltage	Arcs tracing across inside of insulators	6427
202	Mod-anode insulator cracked	Water in modulator tank	1578
222	Ion pump insulator broken	Accidently damaged insulator when moving klystron	307
103-R	Mod-anode insulator cracked	Water in modulator tank	237

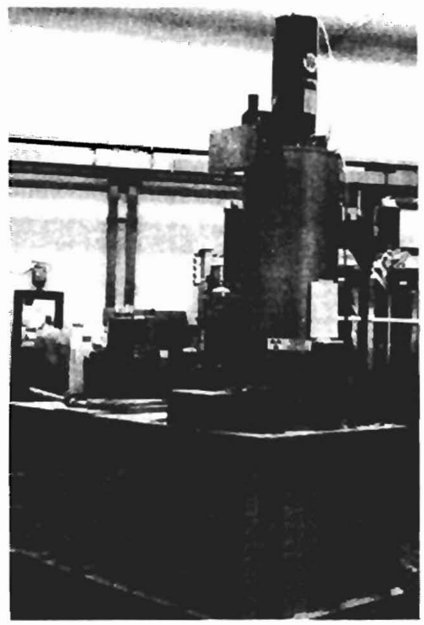

Fig. 1. 805 MHz, 1-1/4 MW rf amplifier module.

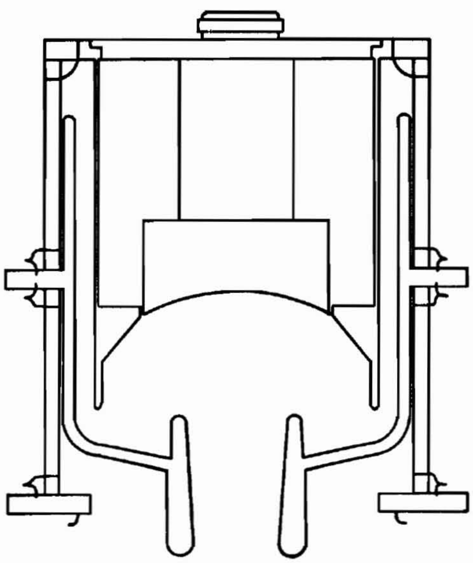

Fig. 2. Klystron electron gun assembly.

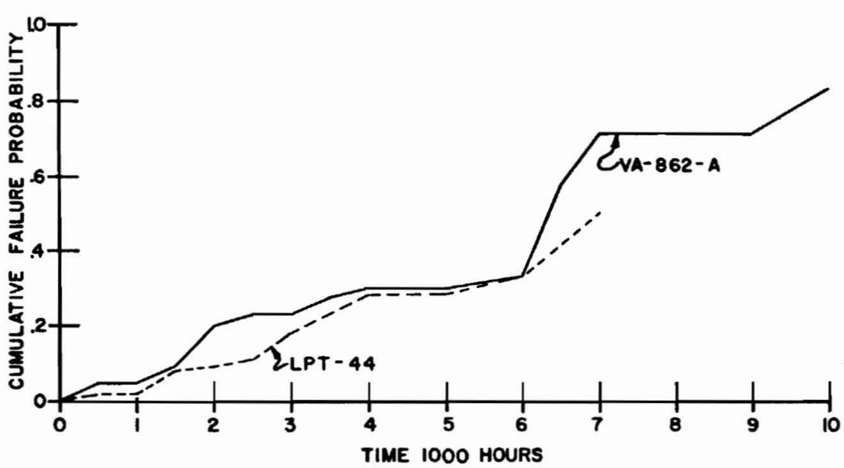

Fig. 3. Cumulative failure probability for LPT-44 triodes and VA-862-A klystrons.