1 of 1

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the Gyrotron System Used on the Microwave Tokamak
Experiment at Lawrence Livermore National Laboratory**

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MEAN TIME BETWEEN FAILURES (MTBF) AND AVAILABILITY OF THE GYROTRON SYSTEM USED ON THE MICROWAVE TOKAMAK EXPERIMENT AT LAWRENCE LIVERMORE NATIONAL LABORATORY

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ABSTRACT

S.W. Ferguson, D.B. Scilhmer, M. Jackson, Lawrence Livermore National Laboratory, Livermore California 94550. This paper presents an analysis of the mean time between failures (MTBF) and availability history of the Varian VGT8140, 400 kWatt, 140 GHz Gyrotron that was operated on the Microwave Tokamak Experiment (MTX) at the Lawrence Livermore National Laboratory (LLNL).

INTRODUCTION

The Varian VGT-8140 gyrotron was operated at a power level of 400 kW for 100 ms in conjunction with MTX plasma shots. The gyrotron system is comprised of a high voltage (~80 kV) modulated power supply, a multi-station CAMAC computer control, a 5-tesla superconducting magnet, a series of conventional copper magnets, a circulating fluorinert (FC75) window cooling system, a circulating oil cooling system, a water cooling system, and microwave frequency and power diagnostics. Additionally, a Vlasov launcher is used to convert the gyrotron TE 15,2 mode to a gaussian beam. The gaussian beam from the Vlasov launcher was transported to the MTX tokamak by a series of 5 mirrors in a 35-meter-long, high-efficiency, quasi-optical beam transport system. No windows were used between the Vlasov reflector and the MTX tokamak. Figure 1 shows a block diagram of the gyrotron and the auxiliary systems used in support of the gyrotron.

The MTX gyrotron system was operated for 730 hours between June 7 and August 31, 1992. During this time the system experienced 5 failures. These 5 failures required a system down time of 15 hours to repair. This corresponds to a system availability of 97.9% and a system mean time between failures (MTBF) of 146 hours. The 15 hours of system down time were caused by 5 failures as shown in Table 1.

During the last three months of operation the gyrotron system exhibited exceptional reliability and availability. Some of the system failures that did occur were caused by persistent design flaws that had not been corrected during system operation. These failures were the body current FO link failure and the 2 computer link failures. Since these failures were not the random failures used in reliability calculations, they should be eliminated from the calculations of system reliability (MTBF) and availability. Eliminating the

design flaw failures leaves 2 failures in 730 hours of operation with a system down time of 8 hours.

MTBF = Operating Time/ No. of Failures= 730/2

MTBF = 365 Hours

MTTR = Mean time to Repair

MTTR = Total Repair Time/No of Failures = 8/2 = 4 Hours

Availability = $100 \times \text{MTBF} / (\text{MTBF} + \text{MTTR}) = 365 / (365 + 4) = 98.9\%$

Table 1
Gyrotron Failure Summary

<u>Failure</u>	<u>Time To Repair</u>
Mod/Reg 5kV Rectifier	4 Hrs.
FC 75 Flowmeter	4
Body Current FO Link	6
Computer Link	2.5
Computer Link	2.5
	15 Hrs. Total

The following is a general discussion of the gyrotron problems and failure trends. Historically, the most common failure in the Gyrotron system was the Mod/Reg cathode and anode current monitoring circuitry. When the system would experience a tank arc, the current monitors on the fast telemetry transmitter card would fail. The failures ranged from I.C. chips to the cards voltage regulators. This happened frequently, about once for every week of operation. zener diodes were added on the signal lines, transorbs were added to the power lines, plus m.o.v's and filter inductors were added to the a.c. lines. The modifications were started on 10/27/91 and finished on 5/7/92. Since we performed the modifications, there were no failures on either the cathode or the anode current monitors.

Another failure, much less common than the current monitors, has been in the gyrotron's body current monitoring. A tank arc would occasionally "lock up" the body current fiber optic instrumentation link. Removing power and then reapplying power to the transmitter module seemed to clear the problem. This occurred at least 3 times. Another failure in the body monitor has been the introduction of water between the tube body and the cryostat bore. Since the tube

FIGURE 1
400 k WATT GYROTRON
SYSTEM BLOCK DIAGRAM

body is isolated from ground and the cryostat is at ground potential, leakage through the resistance of the water can give erroneous body current readings. The water is either coming from a leak in the water lines around the tube, or from condensation forming on the inside of the cryostat bore. To fix this we either lifted the tube and dumped the water into the dielectric oil tank or we tried to evaporate it by running a small current through the water leakage path. This problem happened frequently during the first year of gyrotron operation but has only happened once in the last year of operation.

In the ADCPS (AC DC Power Supply) system there was only one recurring problem. The 13.8 kV line switch would, for no apparent reason, open 3-5 seconds after the operator tried to close it. This caused a major failure when it opened while under load, or while charging the TCC capacitor bank. To remedy this, the capability to operate the switch remotely was removed. The switch had to be operated locally from the ADCPS local control station which was about 1000 feet from the experiment.

The transient suppresser capacitor bank (TCC) has also failed several times since gyrotron operation began. The biggest problem was the hard and soft grounds. On occasion, the strings which actuate the contacts would break. This dropped the grounds on a fully charged bank. We have blown soft ground resistors and 10 capacitors have been removed from service. The electronic crowbar circuit in the TCC works fine with one exception. The Mod/Reg does not issue a

crowbar command when 5kV ready interlock faults. This will drop the soft grounds on a fully charged bank (5kV ready must be present for the soft grounds to be raised). This usually happens when SF6 pressure is lost or the area interlock has been broken.

The control computer system fails from time to time and this will stop the TACL control program. If the system is operating when this occurs, the operator must manually disable the pulse, manually crowbar the capacitor bank, then stop and restart the TACL program. This has happened on the supervisor computer and both local network computers.

The problems mentioned above were experienced and corrected during the first year of operation. During the last three months of operation, the gyrotron system exhibited exceptional reliability and availability. The system MTBF was between 146 and 365 hours depending on which failures were counted as random failures versus design problems and the system availability was between 97.9% and 98.8%.

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