√

MASTER

UCRL-85644
PREPRINT
Conf-810659--31

Thyratron Characteristics Under High di/dt and High-Repetition-Rate Operation

D. Ball, J. Hill and T. Kan

This paper was prepared for submittal to
3rd IEEE Intl. Pulse Power Conference
Albuquerque, NM
June 1-3, 1981

May 11, 1981

Lawrence
Livermore
Laboratory

DISCLAIMER

THYRATRON CHARACTERISTICS UNDER HIGH di/dt AND HIGH-REPETITION-RATE OPERATION*

UCRL--85644

DE82 011158

D. Ball, J. Hill and T. Kan
Lawrence Livermore National Laboratory
P. O. Box 5508
Livermore, CA 94550

Summary

Power conditioning systems for high peak and average power, high repetition rate discharge excited lasers involve operation of modulator components in unconventional regimes. Reliable operation of switches and energy storage elements under high voltage and high di/dt conditions is a pacing item for laser development at the present time. To test and evaluate these components a Modulator Component Test Facility (MCTF) was constructed.

The MCTF consists of a command charge system, energy storage capacitors, thyratron switch with inverse thyratron protection, and a resistive load. The modulator has initially been operated at voltages up to 60 kV at 600 Hz. Voltage, current, and calorimetric diagnostics are provided for major modulator components. Measurements of thyratron characteristics under high di/dt operation are presented. Commutation energy loss and di/dt have been measured as functions of the tube hydrogen pressure.

---

* Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

Introduction

Scaling gas discharge lasers to average power levels appropriate for laser isotope separation plant applications requires the development of adequate electrical power conditioning systems. Such systems must have the power capability to drive the high average power lasers plus sufficient reliability for plant operation. The problems associated with developing the power conditioning system arise from scaling the pulse repetition frequency (PRF) and operating voltage of the laser. The choice and characteristics of switches capable of high average power and high voltage operation are critical to successful laser development.

Hydrogen thyratrons have long been used as high voltage switches for high rep rate applications such as radar modulators. High power laser modulators require high voltage, high rep rate, and high di/dt switch operation not generally needed for line-type modulators. Recent thyratron development has aimed at increasing the voltage and di/dt capabilities of high power tubes.(1,2) The problems of integrating these new switches into a functioning system together with the effects of scaling modulator parameters introduce major uncertainties into the design and performance of laser power conditioning systems. The Modulator Component Test Facility (MCTF) was constructed to evaluate modulator component performance at full peak and average power stress thus reducing these uncertainties and improving the relative success of laser development.

Circuit Design

The MCTF design emphasizes flexibility of testing components such as thyratrons in a manner relevent to high power laser applications. The laser operating parameters require several parallel thyratron switches capable of high power operation at voltages above 40 kV. The stress on a single thyratron is simulated in the test facility. Typical operating parameters for the MCTF are summarized in Table 1.

Table 1. MCTF Characteristics

Charge voltage	60 kV
Energy stored per pulse	14 J
Thyratron current pulse	6 kA peak 100 ns FWHM
Rate of rise of thyratron current	$>10^{11}$ A/S
PRF	2 kHz

The MCTF consists of the 5 major sections shown in Fig. 1. An adjustable high voltage dc power supply energizes the command charge circuit. A step-up pulse transformer provides higher voltages to the power modulator than would be available from the supply. The thyratron under test is contained in the power modulator section. The main thyratron switch, inverse thyratron, and energy storage capacitors simulate a fraction of the entire modulator system for a high power laser. The laser load is simulated with a resistive load using a flowing salt solution as the electrolyte. All components are immersed in oil to provide both high voltage insulation and adequate component cooling at high power dissipation levels. The oil tank containing the transformer and power moudulator is shown in Fig. 2. Design of the power modulator oil tank provides the capability of testing several different sizes of thyratrons and capacitors while maintaining a low inductance configuration. The transformer, main thyratron, inverse thyratron, and energy storage capacitors are each separated by plexiglas barriers. Separating each component provides individual oil circulating systems suitable for calorimetry measurements. The command charge circuit is located in a separate oil tank with its own calorimetry diagnostics.

Thyratron Performance

One of the major objectives of the MCTF is to evaluate thyratron performance under high-voltage, high-power laser modulator conditions. Initial operation of the MCTF involved evaluation of multi-gap thyratron performance at voltages from 38 kV to 60 kV. The first thyratron tested was an EG & G HY-5301 which is a two-gap version of the HY-53. Two such thyratrons were operated in the MCTF, one as the main switch and the other as the inverse diode. Initial operation involved testing the system performance and reliability up to 60 kV at 400 Hz.

After testing high voltage modulator operation, characteristics of the HY-5301 as the main switch were measured. A low-inductance single-gap HY-5313 replaced the HY-5301 as the main switch, and the same measurements were repeated to compare thyratron charcteristics in identical circuits. Both thyratrons were triggered on the control grid from a 2 kV, 40 ohm driver having a pulse width of 0.5 μs.

The holdoff voltage and di/dt were measured at various reservoir voltages and the results are shown in Figs. 3 and 4. Compared to the HY-5313, the HY-5301 holdoff voltage is more sensitive to changes in reservoir voltage. It should be noted, however, that for a given reservoir voltage, the pressure in one thyratron may differ from that in the other. Both tubes were operated with a voltage charge time of 4 μs and a holding time of 1 μs. All di/dt measurements were made at 200 Hz and 38 kV charge voltage. The main thyratron current was measured with a current transformer. The effect of the low inductance structure of the HY-5313 is shown in its higher di/dt at all reservoir voltages. The anode voltage fall time measurements of Fig. 5 were made with a large inductance added to the discharge circuit to prevent voltage drops due to the tube inductance. The fall time was measured from 90% to 10% of the peak voltage. At a given reservoir voltage, the HY-5313 fall time is much less than that of the HY-5301. The percent dissipation curves in Fig. 6 show that operation at a reservoir voltage above the nominal 4.5 V reduces dissipation while increasing di/dt. Fig. 7 indicates that thyratron dissipation decreases slightly with increased PRF. This could be caused by increased gas pressure at a given reservoir voltage due to thyratron heating. For these measurements, the reservoir voltage for the HY-5301 was 5.0 volts and 5.25 volts for the HY-5313. These reservoir voltage values were chosen to provide a holdoff voltage of 52-53 kV.

Conclusions

A facility for evaluating gas discharge laser modulator components has been constructed, and component tests are currently being made. Initial measurements have characterized important thyratron parameters for two different thyratrons. Since switch lifetime and efficiency may be increased by reducing commutation loss, thyratron dissipation becomes an important factor in laser modulator performance. Dissipation and di/dt measurements emphasize the need to operate thyratrons at higher than normal reservoir voltages to reduce dissipation while increasing di/dt. For our desired laser modulator circuit, the HY-5313 provides sufficient voltage holdoff (>50 kV) and relatively low dissipation (<9%) at high reservoir voltages. Effects of different triggering methods on dissipation should be investigated along with studies of thyratron lifetime. More measurements on other thyratrons should be made particularly to determine dissipation characterisitics at higher rep rates and higher voltages.

References

1. R. Caristi, S. Friedman, S. Merz, and D. Turnquist, "New Developments in Super-Fast, High-Power, Hydrogen Thyratron Switching," IEEE Trans. on Electron Devices, Vol. ED-26, No. 10, October 1979.
2. D. Turnquist, "Thyratron Development for High Repetition Rate Gas Lasers," Proc. of the International Conference on Lasers '79, December 1979.

Figure Captions

Fig. 1 Simplified circuit diagram of MCTF system

Fig. 2 MCTF modulator tank

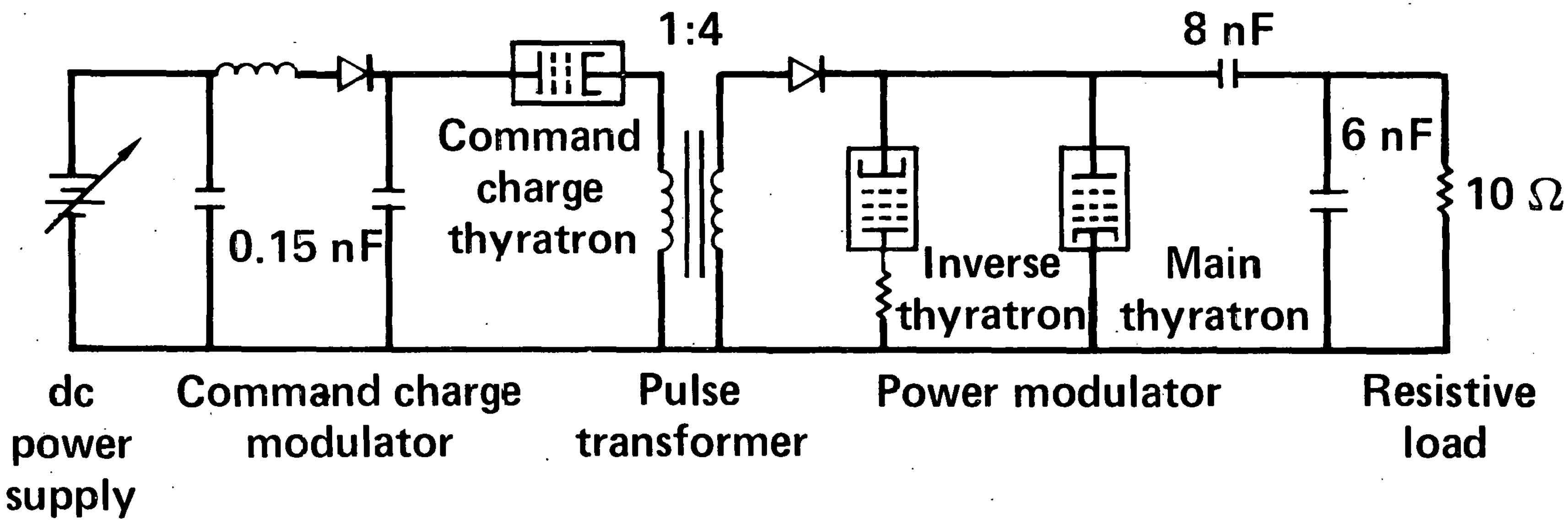
Fig. 3 Variation of holdoff voltage with reservoir voltage

Fig. 4 Reservoir voltage dependence of di/dt at 200 Hz and 38 kV

Fig. 5 Anode voltage fall time vs. reservoir voltage measured in a high inductance discharge circuit

Fig. 6 Percent of thyratron dissipation as a function of reservoir voltage at 200 Hz and 38 kV

Fig. 7 PRF dependence of percent of thyratron dissipation.
HY-5301 at 5.0 volts on reservoir
HY-5313 at 5.25 volts on reservoir
38 kV charge voltage



30-01-0581-1280

Figure 1.

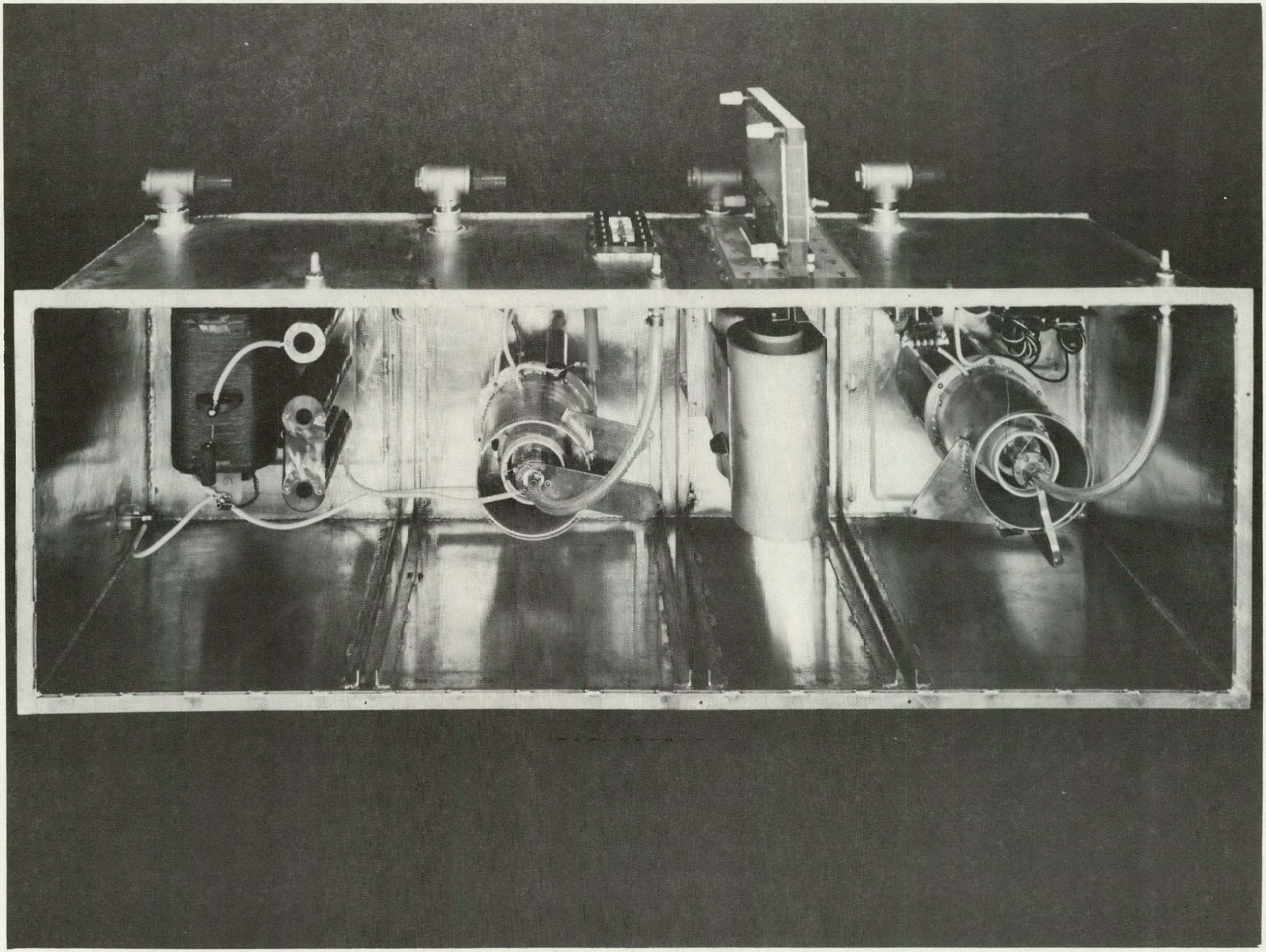
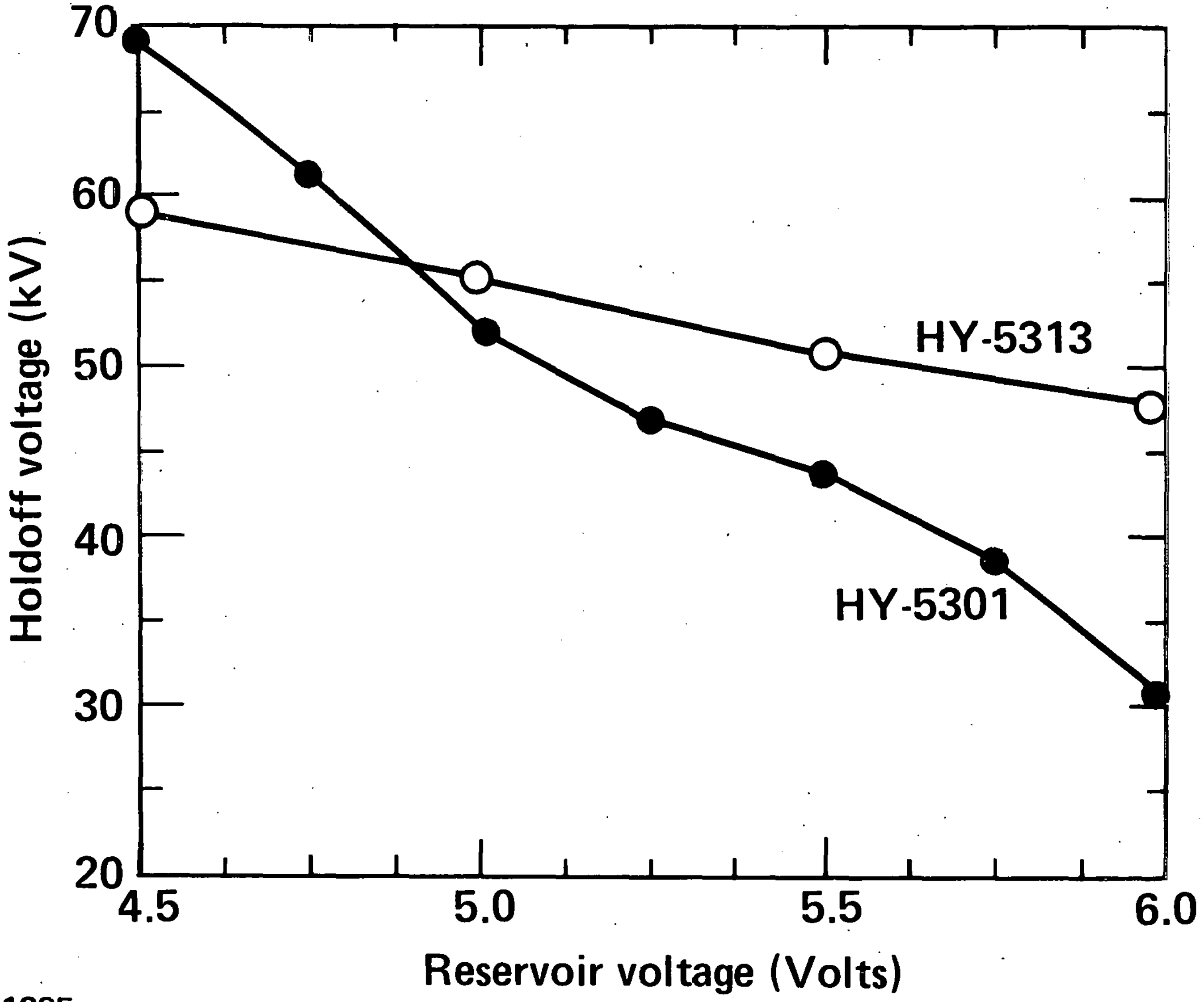
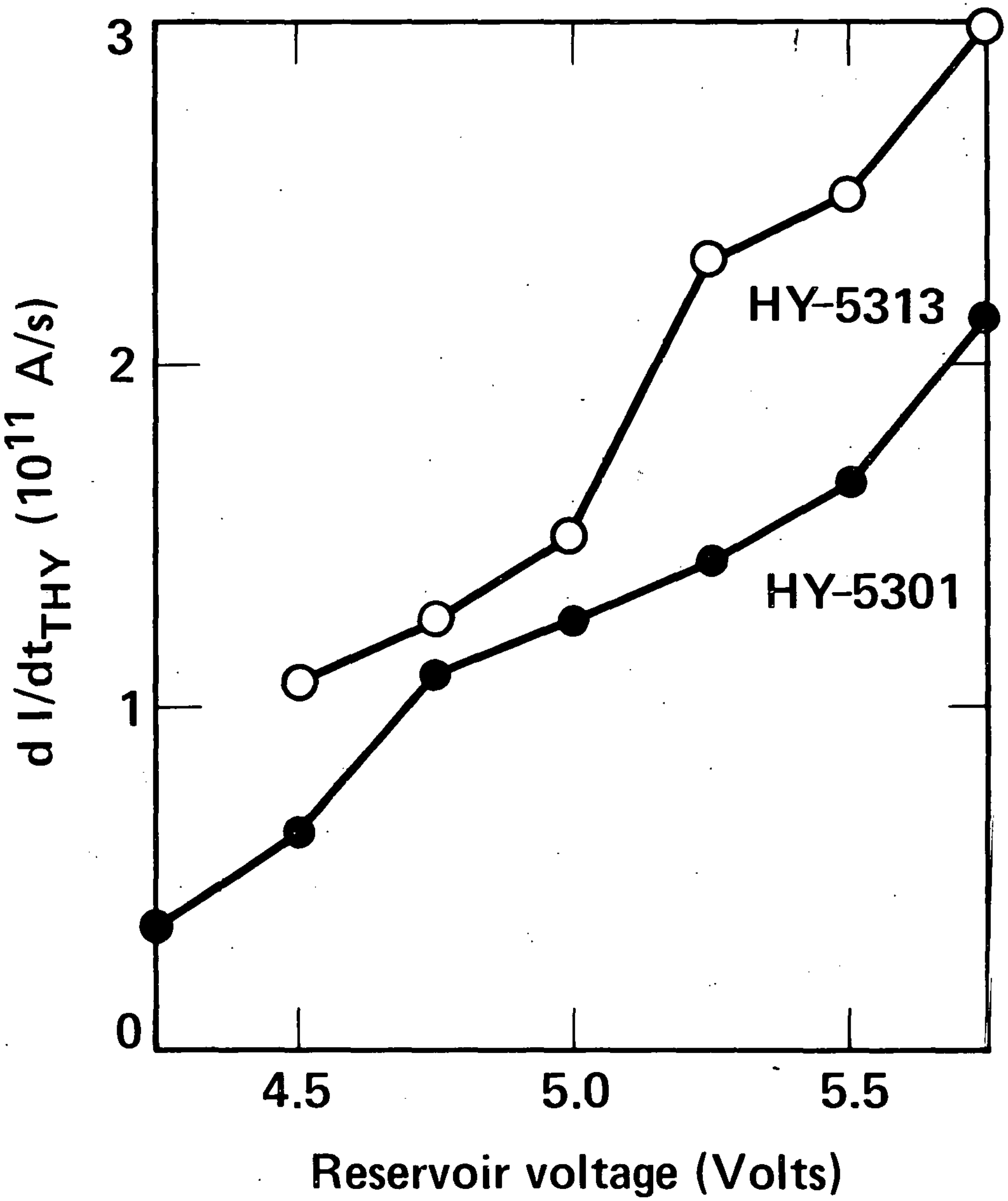


Figure 2.



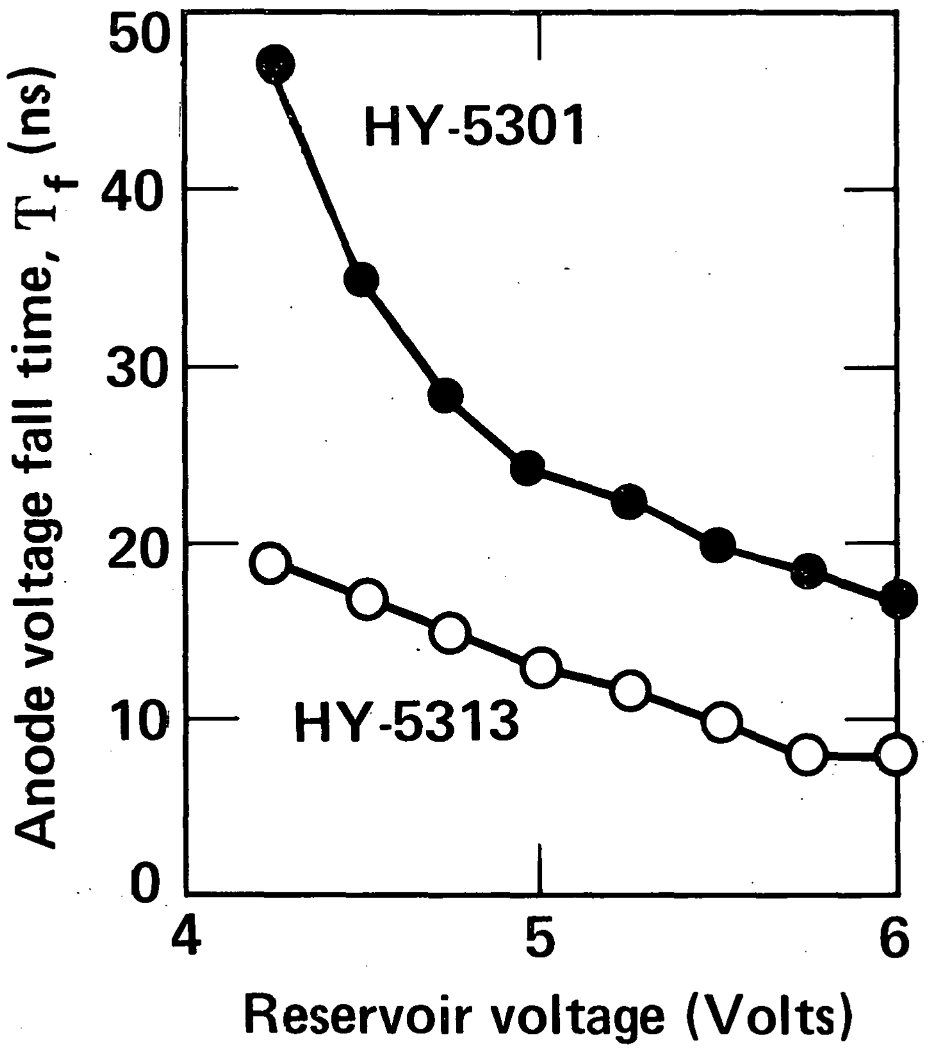
30-01-0581-1285

Figure 3.



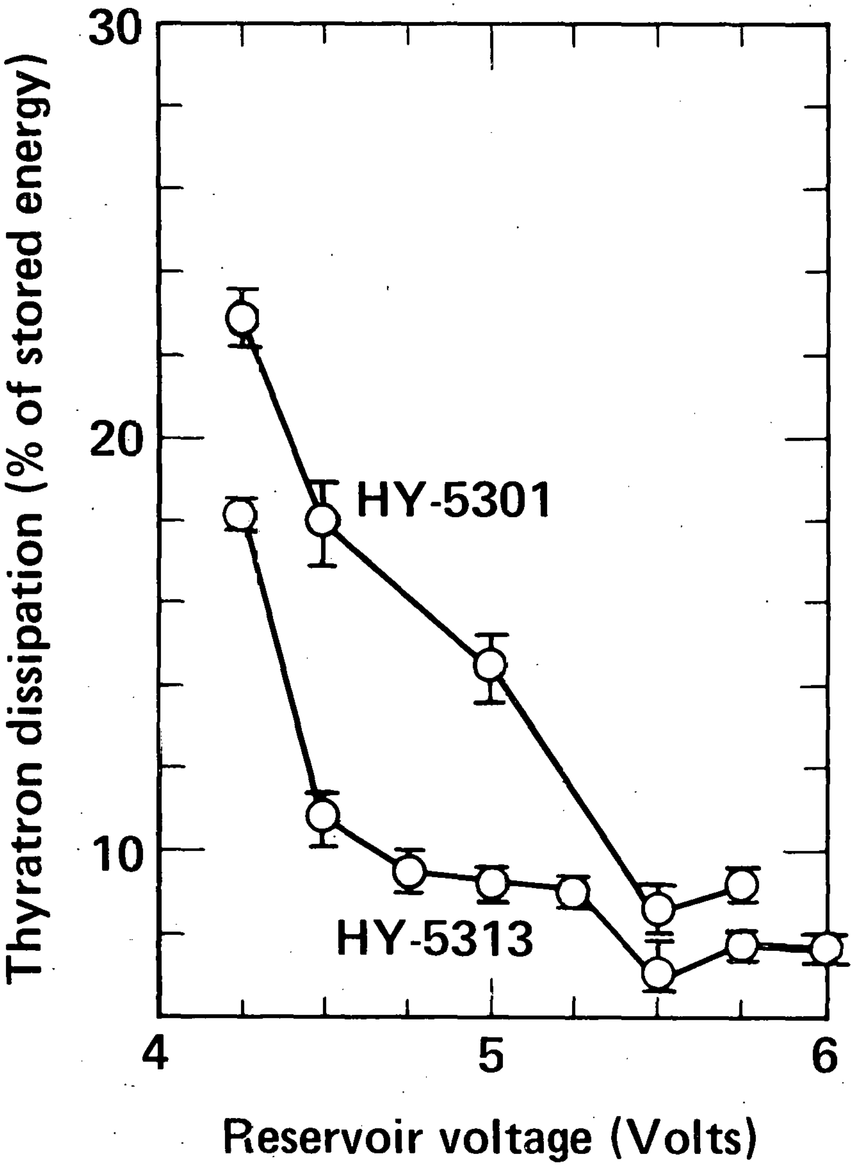
30-01-0581-1282

Figure 4.



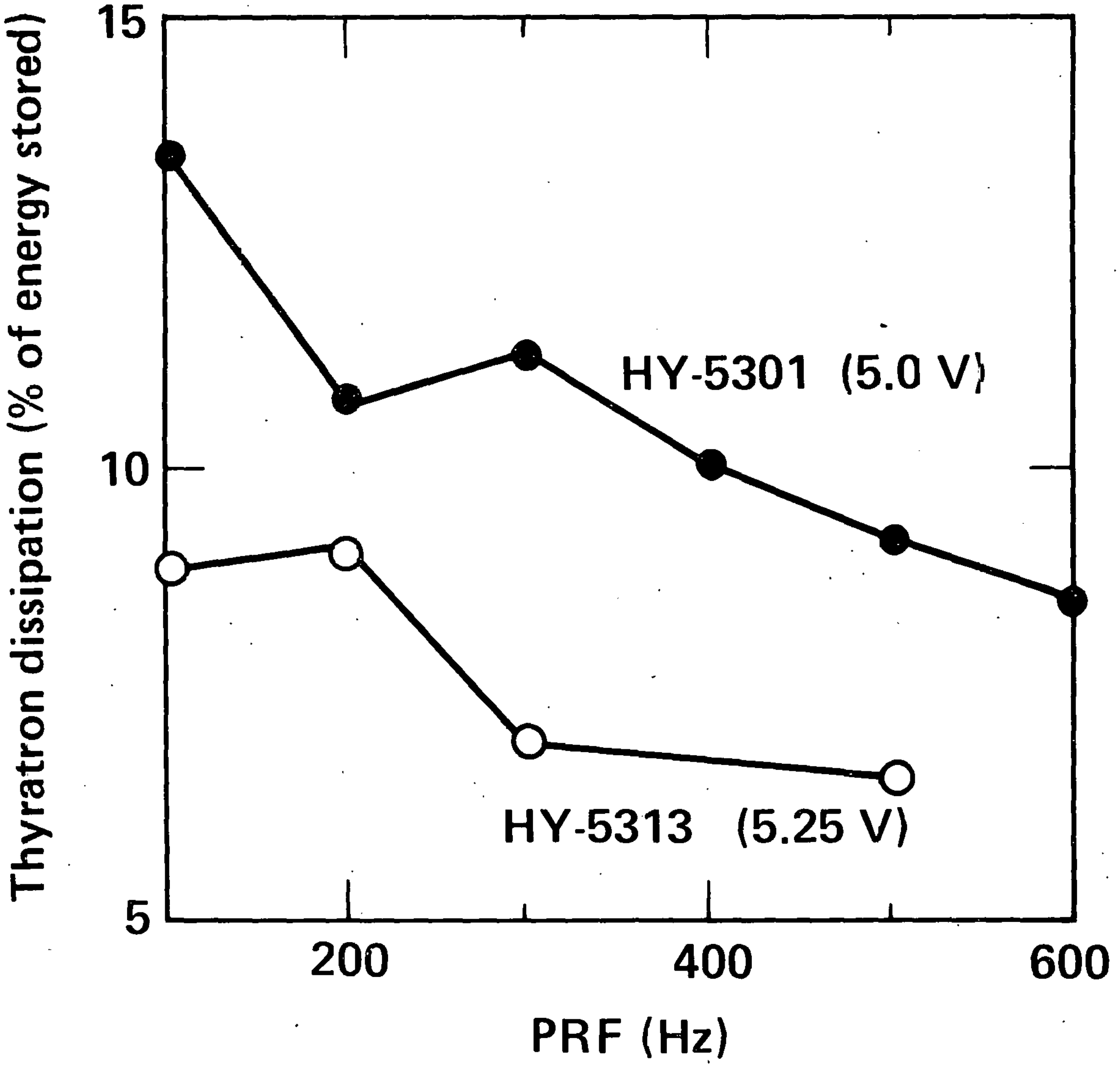
30-01-0581-1283

Figure 5.



30-01-0581-1284

Figure 6.



30-01-0581-1281

Figure 7.

Technical Information Department · Lawrence Livermore National Laboratory
University of California · Livermore, California 94550