HIGH-POWER RF OPERATIONS STUDIES WITH THE CRITS RFQ*

G.O. Bolme, D.R. Keffeler, V.W. Brown, D.C. Clark, D. Hodgkins, P.D. Lara, M.L. Milder,
D. Rees, P.J. Schafstall, J. D. Schneider, J.D. Sherman, R.R. Stevens, T. Zaugg
Los Alamos National Laboratory, Los Alamos, NM 87545 USA

J.Y. Sheikh, A.D. Davidson, and B.H. Smith
Chalk River Laboratories, Chalk River, Ontario K0J1J0 Canada

High-current, cw linear accelerators have been proposed as spallation neutron source drivers for applications to tritium production, transmutation of nuclear waste, and safe nuclear power generation. Key features of these accelerators are high current (100 mA) low emittance-growth beam propagation, cw or high duty-factor operation, high efficiency, and minimal maintenance downtime. A 267.1 MHz, cw RFQ and klystrode based RF system were obtained from CRL[1] and installed at LANL to support these next generation accelerator studies. The reconditioning of the RFQ accelerator section to its design power of 150 kW at 100% duty factor is being accomplished with studies focusing on the details of high-power RF structure operation, personnel and equipment safety systems integration, and RF controls integration.

I. INTRODUCTION

The Chalk River Injector Test Stand (CRITS) RFQ was the 267.1 MHz, cw proton accelerator section from the Chalk River Laboratories (CRL) RFQ1 program, a program to develop 100% duty factor, high-current proton accelerators. This accelerator section is the second version of the RFQ operated at CRL and provides a 1.25 MeV output beam. The RFQ is powered by a 250 kW, klystrode-based amplifier system which was also commissioned at CRL[1]. The accelerator section and support equipment were obtained under contract from the Chalk River Laboratories and installed at Los Alamos National Laboratory (LANL) with the purpose of supporting studies applicable to the operation of high-power, cw accelerators.

II. INSTALLATION

The RFQ was shipped from CRL with a minimal amount of disassembly. Components such as the driveline, slug tuner assembly, and vacuum pumps were removed in order to reduce shipping size and preclude damage to protruding apparatus. Because of the robust design of this RFQ, it was decided to reassemble the RFQ and measure the RF parameters rather than proceed through further mechanical examination for shipping damage. The RFQ resonant frequency, driveline coupling (β), and Q were measured and compared to similar measurements originally made at CRL[2].

	CRL	LANL
f_0 (MHz)	267.1	267.15
β	1.15	1.18
Q_u	7325	7150

The close agreement of the RFQ parameters and the further integrity of the vacuum and water coolant systems provided the assurance that high-power RF operations could be commenced with minimal risk.

III. CONDITIONING

The RFQ was operated at its design field level at CRL with a measured peak input power of 150 kW. Although the RFQ had been previously conditioned to the design field level and had sustained cw operation, the reconditioning at LANL was done in a conservative manner in case unobserved shipping damage had occurred.

The RF directional couplers and RFQ monitor loops were calibrated for power measurement by three redundant systems -- a power meter, peak-to-peak RF signal measurements, and crystal detectors. Spark and light emissions from the RFQ were monitored remotely by video, and vacuum and temperature readouts were available for observation.

Initial reconditioning was done using pulsed power. The RF system was pulsed at a 60 Hz rate with the pulse length advanced throughout the conditioning process. The initial pulse length (167 μsec) resulted in a 1% duty factor, and the RFQ was conditioned up to a measured peak power of 150 kW. This process was repeated at increased duty factors up to 50%.

At 100% duty factor, it was determined that sparks inside the vacuum region of the RFQ system developed

*Work supported by the United States DOE, contract W-7405-ENG-36.

into arcs which were sustained by the available cw power. These sustained arcs sputtered the copper in the driveline resulting in damage to the vacuum window. It was learned at CRL that providing a momentary power interruption quenched the arc and protected the system from damage. An RF blanking module was developed which interrupted power upon the detection of high VSWR (reflected power) and provided a ramped turn-on after system recovery. The key features of this module were the detection of the high VSWR, a response feature providing a brief RF OFF period, and a ramped restoration of RF power to minimize repeat sparks. Through the use of this module, power could be restored to the RFQ within 50 µsec, a desirable feature for future high-intensity accelerators. Because this module protected against system damage, its design featured a no-deadtime requirement allowing it to protect against repetitive sparks. During the integration of this module at CRL, it was determined that the optimal configuration provided blanking to the RF drive setpoint rather than attenuation of the RF power between the low-level RF amplifier and the intermediate drive amplifier[1]. Recent modifications integrated the setpoint control within the module. The setpoint response to a spark is shown in Figure 1 and the resulting RF response is shown in Figure 2.

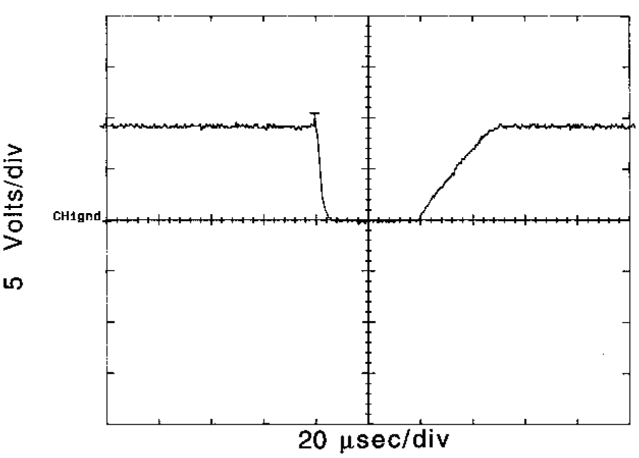

Figure 1. RF power drive setpoint response to an RFQ spark.

With the protection of the blanking module, cw conditioning was completed to a measured power of 150 kW.

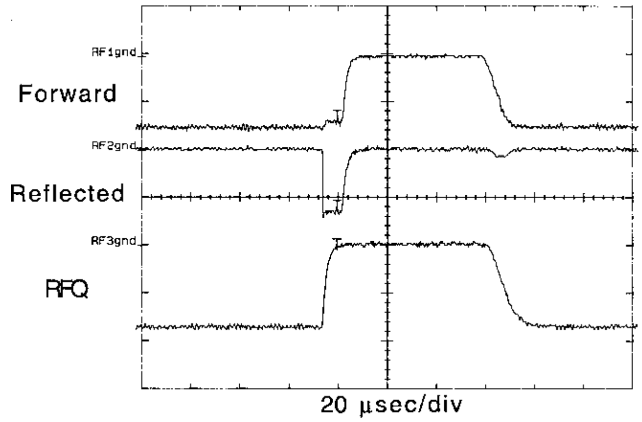

Figure 2. 267.1 MHz video envelope signals (negative signals) resulting from an RFQ spark.

IV. FIELD MEASUREMENT

The RFQ peak intervane gap voltage was measured at several powers using the x-ray endpoint technique[3]. Figure 3 displays the peak gap voltage as a function of measured RFQ power and a fit to the data.

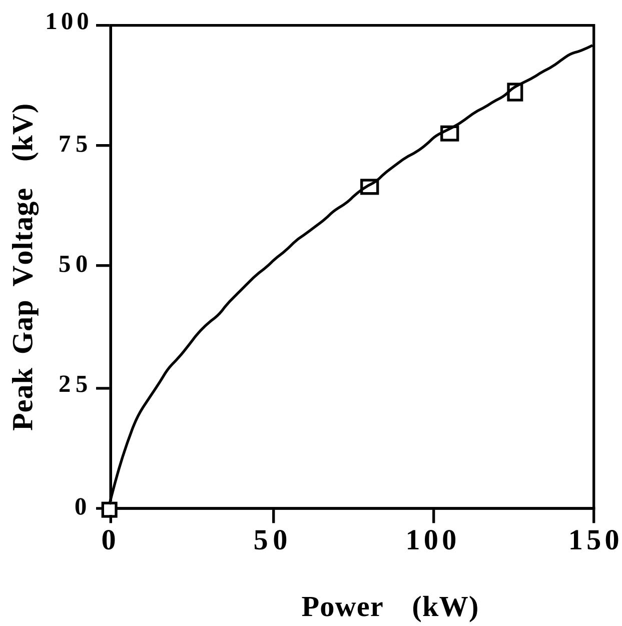

Figure 3. Peak intervane gap voltage as a function of measured RF power.

The measurements indicate that the design intervane peak gap voltage of 77.4 kV is reached at a measured power of 105.0 kW. This power level is far less than predicted by simulations and previous CRL measurements. The discrepancy between the required power as predicted and measured at CRL and that measured at LANL is probably due to inaccuracies in the latest power calibrations and errors in this preliminary x-ray measurement. These measurements will be repeated and the results rechecked.

V. SUMMARY

The CRITS RFQ has been conditioned to the design field levels and has demonstrated the capacity to operate for an extended period without failure. The RFQ is now operational and ready to commence operations with a proton beam.

VI. ACKNOWLEDGMENTS

We would like to thank and express our appreciation to the many named and unnamed personnel at Chalk River Laboratories who designed, fabricated, assembled, and commissioned this accelerator section under the RFQ1 program. Their work has provided us with outstanding equipment to continue the study of cw accelerators and has also provided a strong technical base supporting our future projects.

VI. REFERENCES

[1] J.Y. Sheikh, A.D. Davidson, G.E. McMichael, L.W. Shankland and B.H. Smith, "Operation of a High-Power CW Klystrode with the RFQ1 Facility", Proc. 1993 Particle Accel. Conf., IEEE 93CH3279-7, p. 1175.

[2] J.Y. Sheikh, Private Communication.

[3] G.O. Bolme, G.P. Boicourt, K.F. Johnson, R.A. Lohsen, O.R. Sander, and L.S. Walling, "Measurement of RF Accelerator Cavity Field Levels at High Power from X-ray Emissions" in Proceedings of the 1990 Linear Accelerator Conference, LA-12004-C,219 (1990).