BNL-101910-2014-TECH

AD/RHIC/RD/127;BNL-101910-2013-IR

Operation of the RHIC Beam Dump Thyratron CX1575C

H. Hahn

August 1999

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

AD/RHIC/RD-127

RHIC PROJECT

Brookhaven National Laboratory

Operation of the RHIC Beam Dump Thyratron CX1575C

H. Hahn and A. Dunbar

August 1999

OPERATION OF THE RHIC BEAM DUMP THYRATRON CX1575C

H. Hahn and A. Dunbar

OBJECTIVES & PROBLEMS

Each of the five beam dump kickers in one ring are pulsed by a separate power modulator, the main components of which are the Pulse Forming Network ("PFN"), the deuterium thyratron EEV CX1575C to hold off voltage, the trigger circuitry, and the DC power supply common to all five units. Design parameters for the PFNs are a peak current of 21 kA at 33 kV which allows for one kicker missing. Acceptance pulse testing of the PFNs showed pre-fire, i.e. un-triggered current discharges, starting at about ~30 kV and subsequent failure to hold the voltage for the 10 hour storage time. Current discharges during beam storage would result in uncontrolled beam deflection and beam loss, obviously an unacceptable state. Since collider operation with five units is possible at 27 kV, the PFNs were high-potted to >40 kV without the thyratrons and pulse tested at 27 kV using the same conditioned tube. All ten PFN's were then installed and wired in the tunnel. Initial collider operation thus will be restricted to 27 kV.

The performance and the limitations of the thyratrons were studied in the laboratory using two different PFN's. A full power PFN with 8.5 uF was used for high current testing, and a high-pot PFN with 20 nF was used for high-voltage testing and conditioning. The thyratron CX1575C was originally selected for this application by Forsyth and Pappas together with EEV. Taken separately, the tube specifications in single shot/ crowbar service are well above the requirements:

DC forward anode voltage 50 kV (vs. 33)
Peak forward anode current 50 kA (vs.21)
Peak reverse anode current 25 kA (vs. 5)
Total conducted charge 18 C (vs. 0.4)

The marginal performance of the tube thus came as surprise to everybody involved.

One of the first exploratory tests were made at the suggestion of Mike Harrison, who recommended to lower the reservoir voltage from the stamped-on value of typically 4.9 ± 0.3 V to about 4 V. Pre-fire at high voltage was indeed reduced or even eliminated but the tube no longer triggered at the injection voltage of ~ 3 kV, and more critical, the pulses were accompanied by white (i.e. metallic) instead of the desirable pink (i.e. plasma) current discharges.

After consultation with Ron Sheldrake from EEV, a series of tests were performed in order to identify the source of pre-fire and hopefully to develop an appropriate operational procedure to achieve design performance. The experience of Chris Jensen at Fermilab, admittedly with a different type of thyratron, suggested that conditioning of the tube is critical to prevent pre-fire. Although the thyratron data sheet gives no explicit instructions regarding the need for conditioning of the tube, EEV agreed that a slow conditioning of the tube may be beneficial. In addition, it was recommended to raise the reservoir voltage by 0.4 V above the stamped-on value, which is based on a 50 kV hold-off voltage.

Together with EEV, a test program for a new tube was developed and the tube S.N. #1636 was conditioned in a week long period and then tested in the presence of three vendor representatives. The tube reached 33 kV without pre-fire but after a limited number of pulses, white inside arcs (i.e metal instead of gas) and outside arcs between grid 3 and 4 occurred. Un-triggered pre-fire arcs then started at 35 kV. It was agreed, that the thyratron S.N. #1498 would be returned to the factory for analysis to determine if forward or reverse current is the source of tube problem. This tube had the highest pulse count of any thyratron tested to date. A *post-mortem* was performed by EEV and the failure analysis report pointed to the adverse effects of the inverse conduction as likely source for trouble. As (temporary) solution, the vendor recommends replacement with a different thyratron model CX3575C, which has an additional anode grid and "enables the tube to conduct inverse current without consequent reduction in its high voltage hold-off capability due to electrode damage". A replacement tube CX3575C, SS#1460, has been provided to RHIC for evaluation testing.

EEV has developed a deuterium-filled gas discharge switch in which properties of spark gaps and thyratrons are combined, and Sheldrage now recommends the use of the HX3002 tube in the RHIC abort PFN's. The peak voltage of this switch tube is listed as 38 kV and its suitability remains to be demonstrated by life-time testing at BNL. Furthermore, the trigger requirements of this tube differ from the present thyratron and would require modification of the existing units. In view of the results presented in this report, it would seem that the RHIC requirements can be satisfied with the present thyratron, and a change of tube type must be justified in the future by long term operational experience.

CONCLUSION AND OPERATIONAL PROCEDURE

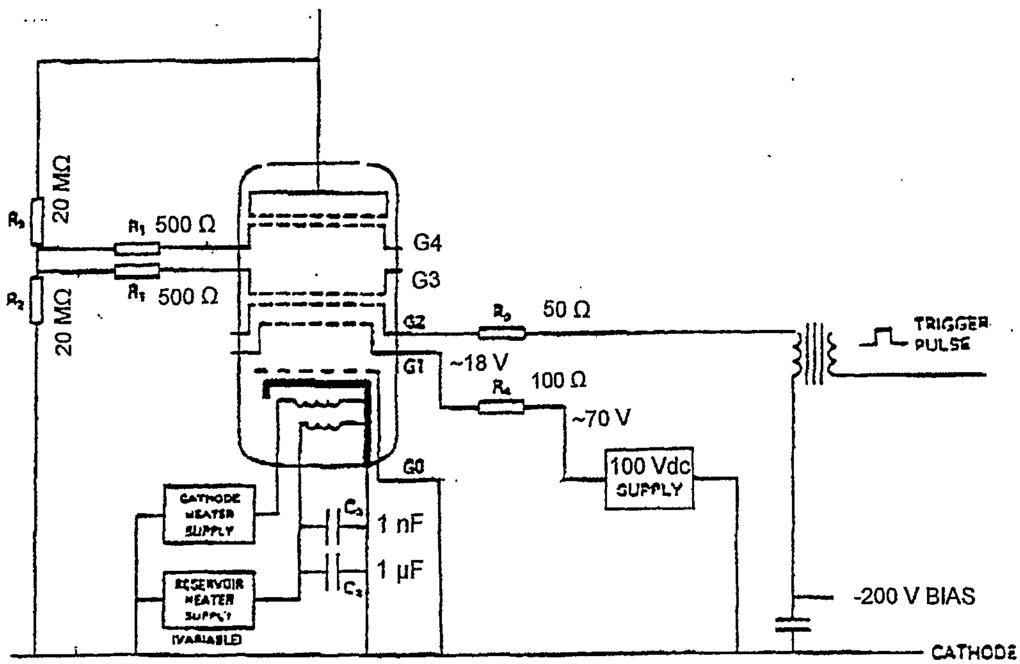
Applying the knowledge gained with these tests, a procedure to allow running at design voltages was developed and successfully applied to the thyratrons S.N. #1630 and #1632. The procedure is based on the premise, that *the reservoir heater voltage should be set to the highest level compatible with the tube hold-off voltage being maintained*, since high gas pressure provides adequate plasma current and prevents ion bombardment and damage of the electrodes. This is recommended in the data sheet for the different purpose of achieving maximum rate of rise of current.

The reservoir voltage at 35 kV is determined in the high-pot PFN , accepting 1 min holding as sufficient. For high-current pulses, the reservoir voltage is set 0.2 V lower. At this level, the undamaged thyratron is holding 40 kV for >10 hours. The hold- off voltage is extremely sensitive to reservoir voltage and tube temperature, thus requiring good, <u>1% voltage control</u> and <u>cooling fan interlock</u>. Obviously, determining the operational reservoir voltage should be done only in the high-pot PFN prior to the ring installation.

Although perhaps not required, a slow conditioning with several 100 full-current pulses each at 5, 10, 15, 20, 25, 27.5, 30, 31, 32 kV, and ~1000 pulses at 33 kV was adopted. Visual monitoring of the pulses to prevent white arcs is necessary. Up to 20 kV, a pulse rate of 3/min, and at higher voltages 2/min are tolerated by the PFN. No attempt to pulse at full current above design is attempted and verification of hold-off voltage above 33 kV can be done only in the high-pot PFN to prevent unintended arcs. Holding the voltage at 40 kV for 10 hours without pre-fire is considered proof that the tube was not damaged by the high-current pulsing.

It is not clear if loss of memory takes place and if repeat of the conditioning procedure is required. According to EEV/Sheldrake this should not be necessary, but FNAL/Jensen reports a month long re-conditioning at the Tevatron after a shut down. Preliminary observations indicate that high-current pulsing at operating voltage (27, or 33 kV) limited to a few shots, just prior to injection, should be sufficient after a normal beam down time between storage cycles. If it should become necessary to condition after a long shut down, round the clock pulsing allows complete conditioning to be accomplished in ~4 days.

ACKNOWLEDGMENTS are due to K. Hartmann and J. Addessi for expert technical support.



SCHEMATIC DIAGRAM for RHIC ABORT KICKER THYRATRON