RHIC Abort Kicker Relays

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Thyratron Prefires

• A prefire is defined as a Thyratron spontaneously discharging a PFN through an abort kicker magnet unintentionally.

• Given the right conditions even one prefire has the potential to cripple a detector or damaging a bypass diode.

• There are 5 kicker modules in each ring. Over a ten year period there have been an average of ~8 prefire per ring each year.

• Even after a great deal of effort there were 7 yellow prefires and 6 blue prefires ( + 4 caused by a bad trigger card) in 2017.

• A three gap configuration of the Thyratron will implemented and tested before the upcoming run begins.
Thyratron Prefires

A solution to this problem would be to put another switch in series with the Thyratron whose prefiring characteristics is decoupled from that of the Thyratron
Plan Going Forward

- Maximum Closing time for the relays must be reduced to 5 msec. The 30 msec delay used last run caused significant problems and equipment damage.

- Operating Time for the 4B and 10A Quench Switches must be increased to 10 msec

- Triggering circuits for the Relay Circuits must be Redundant and confirmed to be armed during operations. (completed for original circuit)

- The system must be exhaustively tested under operating conditions (completed for original circuit)

- The scopes recording kicker currents should be triggered when any kicker is fired
5mS Relay Control Chassis

• Two Relay Control Chassis have been assembled and undergoing testing.

• Bench tests have been done in Pulsed Power Group shop
  • Each chassis was tested to 350 voltage cap bank charging voltage.
  • The operation voltage will be 300 V
  • Primary and redundant chassis were tested energizing one relay
  • Both **Normal Mode** and **Delay Mode** were tested

• The two chassis have been sent to control group for more testing
5mS Relay Chassis Fabrication

Two chassis in control group
• Conventional High Voltage Relay in Air

+ Inexpensive, readily available
  easy to mount, good history in ring
- Originally 40 msec to reliably close
- After Modification 6 msec to close
Plan for Run-18

Abort relays:

✓ Install modified mech. relays (bypassed in tunnel), but ready for complete test. This is done.

✓ Run a series of tests with one bunch at the end of the run including delayed firing of quench switches

✓ Will not use during physics operations
Backup
Present Status

• We have tested different relay coils and can achieve closing times, including bounce time of 5 to 6 msec.

• We have run a life test on the modified relay and have achieve over 5000 operations without a mechanical failure.
RUN 17 Relay Operation Status

• ROSS Relay close time 30mS
• ROSS Relay operation at a PFN voltage 26kV
• Operation ring: Yellow ring
• Two relay control units drover one relay
• There are ten relays be installed in yellow and blue ring
Failed Diode at Sector 10

Edge closest to beam 230 uR/Hr in April

67 mm

2.88 mm thick

Edge furthest from beam

100 uR/Hr in April

After 3 months cool down
65 ur & 39 uR/Hr
What Went Wrong

- When the Quench Detector detects a quench it pulls the quench link and the beam permit link.
- This very quickly (<1.3 msec) fires the Quench switches in 4B and 10A.
- When these switches are fired the current in the Main Ring Magnets quickly decays and the beam will be sprayed all over the
- This occurred on May 14, 2017
- Many magnets quenched but fortunately none were damaged. Many hours were lost in recovery.
- The abort must happen before the Quench switches are fired.
R&D at the E40 ROSS Relay

- E40 ROSS 30mS relay: from last year operation 30mS delay time was too long.
- We tried to modify the E40 ROSS relay
- Tested the E40 ROSS relay with different solenoid
- The modified relay close time is about 5mS.
- We test the modified relay in the yellow abort kicker system.
Modified Ross Relay Test

Modified Ross relay using a DC pulse to drive the solenoid
Relay Close Time New Requirement

• New Close time requirement is
  Relay close time ~ 5 mS

• Modify cap bank and
  • Increase cap bank voltage from 120V to 350V

• Modify Ross E40 relay test
  • Reduce solenoid resistance test from 17.6 ohm to 1 ohm
  • Re design the relay control unit and system
Relay close time test waveforms

Cap bank voltage = 350V

Solenoid resistance = 17.6 ohm
Close time = 5.8mS
Bouncing time = 0.6mS

Solenoid resistance = 7 ohm
Close time = 4.8mS
Bouncing time = 1.2mS
2.6 Ohm Solenoid Abort kicker
PFN Test Waveform

NO Relay 5mS closing time test
2.6 Ohm Solenoid Abort kicker
PFN Test Waveform

Channel 4: with relay
Channel 3: without relay
Original Kicker Requirements

5 Kickers per Ring
Beam Should be aborted if one kicker fails to fire
Typical Voltage           ~27 kV
Typical Current peak      21 kA
**Current Rise Time to minimum Kick**  900ns
Bunch Revolution Time     12.86 us
Abort Pulse Length min    ~13 us
Abort Gap                 1us
Beam must be aborted within 4 turns, 52 us
Maximum delay for redundant trigger 0.7 us
Minimum Jitter            10 ns

These Parameters dictated the use of a Thyatron
What Went Wrong

• Although the system was extensively tested a flaw in the firing circuitry was uncovered when the system was made operational.

• During a normal abort the Blue Kickers are commanded to fire 1 second before the Yellow Kickers.

• The noise from the firing of the Blue Abort Kickers caused the capacitive discharge circuitry in Yellow Kickers to fire prematurely closing the relays in Yellow.

• The Relay capacitive discharge circuitry requires 10 second to charge up reliably after it is fired. When Yellow was asked to fire only 1 or 2 Yellow kickers fired resulting in an extremely dirty abort. Diode Y7D6 experienced high radiation levels while Quenching(?) and was damaged. This occurred on March 11, 2017. Over 83 magnets Quenched.