

Booster Gradient Magnet Test Stand Facility at E4R

David Johnson

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Motivation:

The Booster turned 50 years old in 2017 and we are raising the injection energy from 400 MeV to 800 MeV, increasing the rep rate from 15 Hz to 20 Hz and increasing the injection intensity from $4.5E12$ ppBc to $6.7E12$ ppBc. These changes increased the injected beam power from 4.5 kW to 17.1 kW. To stay below the administrative loss limit, the loss rate must be reduced by a factor of four.

Preliminary calculations have shown that the capacitors in each girder may be replaced with different values to maintain the resonance condition as we change from 15 to 20 Hz. Low power test of girder components indicate that this new rep rate is possible. [Krafczyk, beams-doc 4777] The magnets, themselves have not been tested at full current at 20 Hz. It is very prudent to test these 50-year-old magnets to verify longevity at this new operation mode.

Therefore, we will establish a girder test stand to mimic an operational girder in Booster. This facility should be made up of a spare girder (to be refurbished) the required capacitors, choke, and instrumentation, and a spare GMF and GMD Booster combined function magnets as installed in the Booster tunnel. Water cooling and power supply and controls should allow full power operation. This facility will be utilized for several tasks (as outlined below) including long term operation of the existing spare combined function magnets at the 800 MeV injection level and 20 Hz.

The modifications to Booster for PIP-II injection will include a new injection girder and the replacement of the defocusing gradient magnets (GMD) on either side of the injection girder with shorter gradient magnets. The effective length will be reduced from ~ 2.89 m to ~ 2.13 m to make room for the new injection system. This magnet will still have to produce the same dipole field (bend angle) and gradient as the nominal GMD. Since this magnet will be on the same girder as a standard GMF magnet, it will be powered at the same current which means that the number of turns must be increased, and the field must increase such that the integrals are the same. In addition, it must track the fields of the nominal GMD throughout the ramp. This new magnet will have an increased inductance, so the capacitance of the resonant circuit must be adjusted. This magnet will be tested under operational conditions.

Extraction loss is a key contributor to the total loss budget and this loss must be reduced. The current extraction channel has vertical aperture restrictions, so a wider aperture defocusing gradient magnet (GMDW) is proposed. Current specifications are being determined. It is expected that this magnet will be built, and we must have a facility to test this magnet.

In the 50 years of operation a Booster gradient magnet has not been changed and a girder had not been removed or changed. There are no procedures for either of these activities. Therefore, procedures for replacing a gradient magnet and girder must be developed. It is assumed that the Girder Test Facility can be utilized to develop procedures for girder and magnet replacement.

Location

This facility has been proposed to reside at E4R, the same location at the tests performed in the early 2000's when the test girder was decommissioned and removed from the building. Since that time, the building has become a storage facility.

To utilize the facility again there will need to be a clean-up to remove unused equipment, surplus equipment, and junk. We need to determine the scope and schedule. The water and power will need to be restored, fencing and interlocks installed.

Utilization Plan

1. Designate/appoint facility manager (?)
2. E4R Clean up- There is a lot of equipment that needs to be removed in both the "control rack" area, by the water manifold, the entrance by the MR tunnel sections, and in the tunnel section as well (for about the first 40-50 feet). Owners of the equipment need to be notified for either transfer to surplus, storage elsewhere, recycle, or trash. Much (but not all) of the storage looks to be MS vacuum equipment and components. Hopefully, this can fall right in line with AD cleanup efforts. This will be the first step in preparation.
 - a. Mechanical Support take the lead in this? [Fernando Juarez x8030](#)
 - b. Coordinate this effort with Building Manager [James Ranson x3216](#)
 - c. Get all "permits", HA's, etc. that might be required
 - d. When and how long?
3. Verify water capacity in E4R. (Dez)
 - a. Need flow and pressure drop requirements for power supply and magnets to be provided by EE Support and Proton Source, respectively.
 - b. Mechanical Support to make necessary modifications, if necessary.
4. Verify environmental control capacity, i.e. heaters/air conditioner/lights/etc.
 - a. Would this be building manager?
5. Verify Electrical Capacity and power circuits
 - a. Requirements supplied EE Support
 - b. preliminary investigation looks like circuits are present (need final verification of their status.
 - c. Whom else is involved? Jim Ranson, FESS? Safety?
6. Determine where the power supply will reside and make sure primary is available and cabling/bus for secondary can be installed.
 - a. Preliminary thoughts is that it could reside just outside the tunnel
 - b. EE Support to determine requirements and arrange for connection.
7. Install safety fence/gate for tunnel, where the girder test stand will reside.
8. Determine and install electrical safety permits, interlocks
 - a. EE Support , ES&H , interlocks
9. Establish Policies & Procedures for Operation.
 - a. EE Support
 - b. Mechanical Support
 - c. AD ESH

10. Refurbish girder (Nick Unold x2777)
 - a. sandblast and paint – APS-TD
 - b. reconfigure internal structure of girder – Proton Source & Mech Support
 - c. girder alignment fixtures (stands) and magnet stands – Proton Source?
11. This facility will be used to develop procedures for magnet/girder replacement in the Booster tunnel. This will be very important.
 - a. Mechanical Support
 - b. Proton Source
 - c. ES&H

Measurement Plans and Goals

The baseline goals for establishing this facility are:

- To verify resonant electrical operation of the standard Booster girder (with spare GMD & GMF) at operational current and 20 Hz (verify capacitor and choke parameters).
- Develop a magnet measurement system for DC & AC measurements
- To provide a facility for testing resonant operation & magnetic measurement for new gradient magnets to be used for injection and extraction
- Provide a facility for long term 20 Hz testing of gradient magnets under PIP-II operational conditions.

Potential Initial Measurement Plan

The detailed magnet measurement plan needs to be defined.

1. Establish 15 Hz operation of the spare girder with spare F & D gradient magnets, capacitors, choke and other required components.
2. Make magnet measurements on the magnets under 15 Hz operational conditions. (Detailed measurement plan TBD).
3. Change capacitors to values to run at 20 Hz
4. Install new 20 Hz ramp.
5. Measure magnets under 20 Hz operational conditions.
6. If neither the injection or extraction magnets are available, perform long term 20 Hz operational tests.
7. When the injection and extraction magnets become available, use this facility to verify operation at 20 Hz.

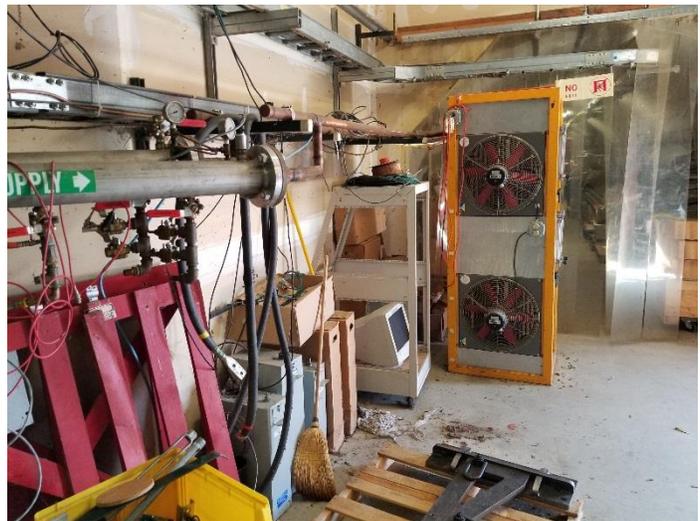
Pictures from ER4 visit 9/17/19:



Control Racks (front and back) to be cleaned up



Storage rack area by door



Potential location for power supply by tunnel



Tunnel to be cleared out. Location of girder on left hand side (needs space either side for full length probe)

After cleanup. Pictures taken 12/17/19



