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FINAL DESIGN AND FIRST USE OF IN-SITU MEASURING APPARATUS FOR MEASUREMENT OF PERMANENT MAGNET RESILIENCY IN CEBAF'S RADIATION ENVIRONMENT*

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Abstract

In this work we outline the final design and initial measurement lessons for the holders and measuring apparatus of the permanent magnet resiliency experiment which is a part of the FFA@CEBAF proposed upgrade. The experiment will expose permanent magnets to the radiation environment of CEBAF. Due to safety regulations we need to measure the magnets in the tunnel without bringing them out, so we designed a mobile measuring system as well as a series of protocols to allow us to speedily measure these samples even under adverse conditions. We also designed our system to be capable of taking measurements even with component failures.

INTRODUCTION

A proposed upgrade for the CEBAF accelerator would use permanent magnets in a Fixed Field Alternating gradient lattice [1]. In order to determine how the permanent magnets will react to a radiation environment, we have created an experiment to leave magnetic material samples in various parts of the CEBAF tunnel while the beam is in operation [2].

Radiation control rules mean that bringing the magnet samples out of the tunnel to measure them would involve sweeping them for potential contamination. Since we are only able to access the tunnel every other week during the experimental run, bringing them out then waiting to put them back in would lose half of the potential radiation exposure time. Therefore, we decided to create an experimental setup that would measure the magnets in-situ [3].

EXPERIMENTAL SETUP

The measurements are made with a Senis AG 3MH6-E Teslameter [4] and a Magnetic Instrumentation, Inc. Helmholtz coil with model 2130 fluxmeter [5]. We capture the data using computer software specifically written for this project. The computer communicates with the Helmholtz fluxmeter and the Teslameter using RS-232 serial connections.

The experimental setup uses exposure plates to hold the samples at particular points in the accelerator. These plates also hold dosimetry, both area dosimeters and small tubes, each of which hold optichromic rods. There are two types of exposure plate, single sample and assembly. Images of the two types of plate are shown in Fig. 1. The single samples are held in holders that contain slots for the Teslameter's probe to fit into. The use of these slots makes sure that we are measuring the same point on each sample as consistently as possible. These sample holders also have notches that make sure they are always put into the correct positions on their plate. We cycled the four different types of samples throughout the different slots to prevent a systematic error that might occur from a sample always being in the same place.

Figure 1: These are the exposure plates for the single samples (top) and assembly holders (bottom).

The assemblies consist of two smaller magnet samples contained in enclosures. These enclosures are then paired up in a holder in one of four different configurations.

- Alpha $\Rightarrow\Rightarrow$
- Beta $\Rightarrow\Leftarrow$
- Gamma $\Rightarrow\Uparrow$
- Delta $\Rightarrow$

The arrow denotes the direction of the north pole. Both in the single samples and in the assemblies we have kept the poles parallel with the plane of the plate. This makes sure that any stray fields perpendicular to the plate will decay faster so that we can place these magnets near the beamline without interfering with beam operations. Much like the single sample plates, we switched which configuration was in each slot to again reduce systematic errors.

Both types of samples use barcodes to aid in data collection. Each sample gets a specific code. Barcode readers work by sending keystrokes to the computer as if they came from a keyboard. The data acquisition software determines what it's reading based on the first character. An R is a tube with optichromic rods, X is an area dosimeter,

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Y is a single sample plate, A is an assembly pair, and H is an assembly holder. Each assembly holder is labelled with Hn or Hs, the N for the Neodymium Iron Boron and S for the Samarium Cobalt magnets respectively. As a backup to the barcode reader we write this code in each single sample and assembly holder. In order to maintain the proper orientation of the assembly pairs in the holder we use two different colors drawn on the assemblies in the holder to make sure that they are reinserted properly after being measured. A photo of this is shown in Fig. 2.

Figure 2: The assembly pairs in their holders, note the different colors to maintain proper orientation.

To measure the magnetic fields using the Teslameter, we have constructed a set of measuring rigs. These rigs serve two purposes, to make sure we are measuring the same point as consistently as possible, and quickly aiding the data acquisition computer to know where to store the information. The measuring rigs are connected to a control box powered by a microcontroller. The rigs operate by using LEDs that shine light through channels to light sensitive resistors. When the data taking button is pressed in the software the computer gets voltages running through the resistors back and determines which slot has the probe in it. It then queries the Teslameter and sends the measured data to the proper fields in the software. The data acquisition software knows which set of resistors to query based on the sample code that was read by the barcode reader. A photo of the measuring rigs is shown in Fig. 3.

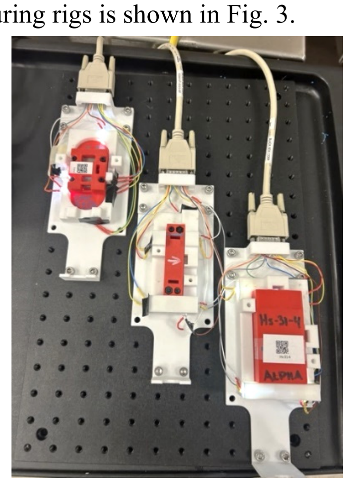

Figure 3: The measuring rigs as they appear on the cart.

Since the Helmholtz coil and Teslameter are large and bulky, we use carts to hold them along with the computer. Since this project started, we have switched to using two computers on two carts, one for the Helmholtz coil and one for the Teslameter. We initially planned on using a single computer and barcode reader simultaneously for both Helmholtz coil and Teslameter, but based on experience in the tunnel we have procured a second laptop and barcode reader. Images of the two carts are shown in Fig. 4.

Figure 4: The two measuring carts in the CEBAF tunnel, on the left is a Teslameter cart, while on the right is the Helmholtz coil cart.

SOFTWARE

The software used to gather the data has undergone a series of improvements since the initial design. A number of error catches and failure warnings have been added to prevent issues caused by connection problems with the Teslameter and Helmholtz coil, accidentally double clicking the data writing button, and trying to save data without scanning all of the relevant barcodes. We have also added a logging function to the software so that we can see which samples we have already scanned and with what instruments.

CEBAF has multiple safety states during operation. We are only able to go into the tunnel when there is either a controlled or restricted access. During a controlled access only a fixed number of people are allowed to enter each linac at the same time, and must be let in by the machine control center. During a restricted access the doors are open and anyone with dosimetry and proper training can enter. The freight elevators that can move equipment down into the tunnels are only usable during a restricted access. Furthermore, the accelerator is broken up into zones, We do not put magnets into the experimental halls or into any of the transfer areas. The CEBAF tunnel, which is comprised of arcs and linacs, is split halfway down the middle. The North Linac comprises the linac on the north side along with the northern halves of each arc, the south linac has the southern linac and the southern halves of each arc.

In order to get an integrated dose measurement for each sample, we need to swap out the dosimetry every other week or so to prevent them from being saturated. Since some weeks the machine will only go to controlled access we can't bring down the carts with our instrumentation on them. In these instances we would bring replacement dosimetry, a laptop, and a barcode reader down into the tunnel, carrying it on our persons instead of on the cart.

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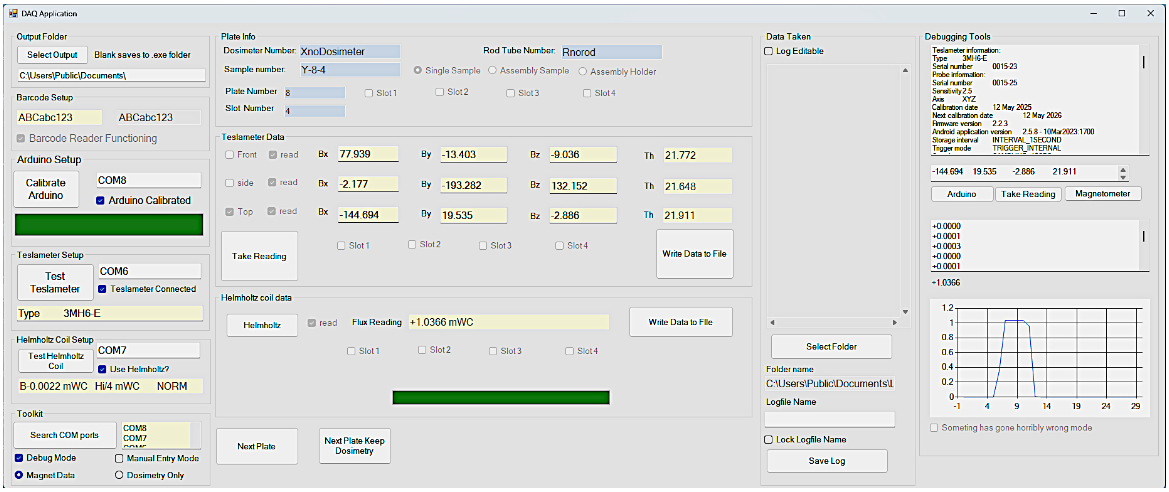

Figure 5: A screenshot of our data acquisition software as it would appear when taking data.

In order to facilitate this we updated the software to include a mode that would allow us to scan a single barcode on a plate, as well as the codes on the area dosimeter and rod tube. The software then writes the dosimeter info to each output file along with a code that shows that we didn't take a field measurement on that day. A screenshot of the software is shown in Fig. 5.

OPERATIONAL LESSONS

Now that we have made multiple measurements, both simple dosimetry swaps and magnet measurements, we have learned a number of lessons for experiments of this type.

When performing a dosimetry swap, we try to have groups of two to three people. One will hold the laptop and barcode scanner, while the other(s) will carry a ladder to reach the plates in the arc regions. Since the barcode scanner is wireless, for plates that are higher up we can have someone climb the ladder, scan the plate and dosimetry, then hand the old dosimetry down and receive the new dosimetry which they will put back into the plates. We write the plate number on both the area dosimeter and the rod tube as a backup. In order to prevent us accidentally putting already exposed dosimetry back into the plate we alternate the color of the pens we use between swaps. With two or three people we can perform a complete dosimetry swap in one linac in approximately 45 minutes.

When performing magnet measurements we employ an assembly line model. The plates are retrieved and the dosimetry is scanned into the computer(s). Then each sample has its barcode scanned, then either the Teslameter will be used to measure each axis, the Helmholtz coil will be used to measure the total magnetization, or both. When measuring the assemblies we first do all of the measurements of the assemblies in the holder, then we have someone who opens up the holders and hands the pair assemblies to the people making the measurements for another pass. Since the software reads the holders and pair assemblies as separate batches, we added a button that would switch to the next plate but keep the dosimetry. This both speeds up data taking and reduces possible sources of error. We also found that the laptops we use for data taking have magnetic sensors that tell the computer when the lid is closed, it is therefore important not to hold the samples to close to the laptop since that can inadvertently cause it to go to sleep. With a skilled crew it takes about 4 hours to fully measure a linac.

CONCLUSION

Now that the permanent magnet experiment is up and running and data is being taken, we have been able to update our equipment and workflow. We have taken the measuring equipment and put them onto mobile carts that we have been able to bring into the tunnel and take measurements with. We have also developed a system that enables us to swap out dosimetry when the accelerator is opened in a way that doesn't allow us to bring carts down into the tunnel. This experimental design and setup allow us to efficiently perform a large, long duration experiment to measure the effects of radiation exposure on permanent magnets.

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